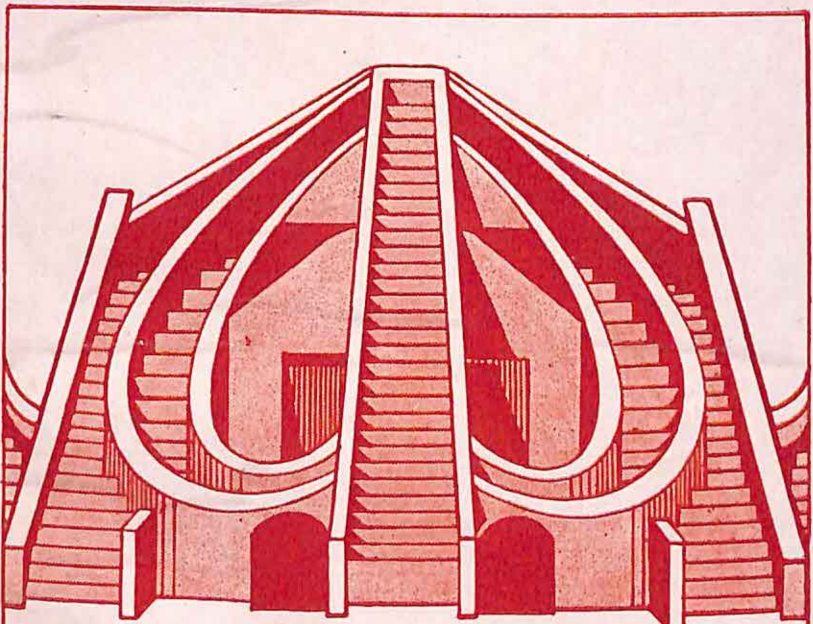
GREAT INDIAN
SCIENTISTS

Pranab Bandyopadhyay



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And

Many Others

SCIENCE IN ANCIENT INDIA

Science in India has an ancient tradition. Ayurveda, astronomy and mathematics are the three important branches of science, in which ancient India was pioneer among other countries in the world. The zero and the numerals, and the decimal system are all rightly recognized as Indian contributions to the advancement of science.

Mathematics began with the invention of numbers to count by *Roman Numerals* : I, II, III, IV, V, .. X etc. invented by the Romans over 2000 years ago. The numbers 1, 2, 3, 4, 5, ... 10 etc. were first used by the ancient Hindus in India. Hence these numbers are called *Hindu Numerals* which are 10–based. Probably number '10' is chosen, since it represents the number of ten fingers on a pair of human hands.

A. L. Basham writes : "Most of the great discoveries and inventions, of which Europe is so proud, would have been impossible without a developed system of mathematics, and this in turn would have been impossible, if Europe had been shackled by the unwieldy system of Roman numerals. The unknown man who devised the new system was from the world's point of view, after Buddha, the most important son of India. His achievement, though easily taken for granted, was the work of an analytical mind of the first order, and he deserves much more honour than he has so far received. Medieval Indian mathematicians, such as Brahmagupta (7th century), Mahavira (9th century) and Bhaskara (12th century), made several discoveries which in Europe were not known until the Renaissance or later."

When the Aryans invaded the Indus Valley some time around 1500 B.C., they found in India a suitable background for fruitful pursuit of science.

The Vedas represented the very best in speculative thinking apart from containing numerous references on drugs, diseases and stars.

Kanad and Kapil, the Vedic philosophers, referred to five 'immertable' elements which were constituents of all matter. They also developed the concepts of *anu* (molecule) and *paramanu* (atom).

Kanad prepared the undulatory theory for the propagation of sound and made the speculation that light and sound waves are only different manifestation of the same energy.

Samkhya, Rig Veda etc. are full of philosophical enquiries about the universe : how it was created ; how life came on to this earth and so on.

The 'Narada Samhita' mentions 18 ancient scholars : Brahma, Surya, Vasishtha, Atri, Manu, Pulastya, Lomasha, Marichi, Angira, Vyasa, Narada, Shaunaka, Bhrigu, Chyavana, Yavana, Garga, Kashyapa, Parashara.

Besides, there are others who are known to have made substantial contributions to various branches of knowledge.

In medicine, the names of Dhanvantari, Bharadvaja, Atreya, Jivaka, Patanjali, Charaka, Susruta, Vaghbhata, Umasvati, Madhavakar, Vrinda, Dridhabala, Bhava Misra, Anandarayamakhi, Jolihtra and Maheswari are well-known, and in astronomy and mathematics, the names of Baudhayana, Garga, Lagadha, Medhatithi, Aryabhata, Srisena, Kanada, Varahamihira and Bhaskaracharya are great names.

Dhanvantari was one of the 'nine gems' that adorned the court of Samrat Vikramaditya : author of the lexicon on drugs 'Dhanvantari Nigantu' (4th century). Sage Chyavana was also a famous Ayurvedic physician. His 'Chyavana Prasha' is used even this day as an useful Ayurvedic medicine.

About ancient Indian medicine, A. L. Basham observes : "Despite their inaccurate knowledge of physiology, which was by no means inferior to that of most ancient peoples, India evolved a developed empirical surgery. The caesarian section was known ; bone-setting reached a high degree of skill, and plastic surgery was developed far beyond anything known elsewhere at the time. Ancient Indian surgeons were experts at the repair of noses, ears and lips. The pharmacopoeia of ancient India was very large, and comprised animal, vegetable and mineral products."

Aryabhata, whose name was given to the first Indian satellite put into orbit, occupies an important place among Indian mathematicians and astronomers of antiquity. His work, *Aryabhatiyam*, forms the foundation of one of the Indian schools of astronomy. Aryabhata was born in 476 A.D., the year in which the Gupta king Buddha Gupta took over the reigns of government of Pataliputra (modern Patna). Among his contributions are :

1. Value of π—3.1416 (correct to four decimal places)
2. Sine Table
3. Theory of indeterminate equations of the first degree
4. Divisions of time (*Kalpa, Manvantara, Yuga)*
5. Theory of earth's rotation
6. Astronomical constants
7. Variable epicyles
8. Positions of Planets

Indus Valley civilization traced in the relics at Harappa and Mahenjo Daro, indicates that the cities and houses were then well-planned with excellent water supply and drainage systems. There was considerable progress in brick-making, crafts, textiles etc. The Aryans were well-advanced in scientific knowledge and experiments. They explained the law of the universe in terms of the *panchabhutas* (five factors) of *kshiti* (earth), *aap* (water), *tej* (heat or energy), *marut* (air) and *byom* (sky). They said that human body was a combination of the *panchabhutas* and the soul.

The ancient Indian astronomers made their luni-solar calendar based on the movement of both the moon and the sun. They identified numerous *nakshatras* (constellations) by naming them after the months. The Vedic texts reveal the knowledge of permutation and combination.

The *Siddhantas* (astronomical treatises) were written by the ancient Indians. *Suryasiddhanta* (the accurate data about the solar system) is very popular all over the world.

During the reign of Emperor Muhammed Shah, a Hindu king named Jai Singh, showed his interest in astronomy and architecture. He designed in 1727 a new city capital at Jaipur and built *Jantar Mantar* (observatories) in 1724 in Delhi, Jaipur, Varanasi, Ujjain and Mathura. The one at Mathura is, however, in ruins at present. In Sanskrit, *Jantar Mantar* means 'instruments and formulae'. The king was assisted by Pandit Vidyadhar Bhattacharya, a Bengali astronomer, in his endeavour. He published his observations in the form of tables in Persian in 1734. They possessed just masonry instruments, and none optical. In the library at Jaipur, of Sawai Man Singh for whom Bhattacharya worked, there are copies of the *Eshemeris* and the

Nantical Almanac and letters from Lisbon, perhaps because of Portuguese presence and influence in India at that time. Newton had not been dead for more than 10 years when the *Jantar Mantar* was erected.

The profound intuition of the Indian ancient seers about the nature of the universe are in a way being confirmed to the findings of science, especially those relating to the structure of the atom.

Geometry

The ancient Hindus were interested in geometry of ritual altars for sacrificial fire. The *Kalpa-sutra*, a ritual Vedic text, had an important supplimentary, *Sulya-sutra* (rules of the thread or 'measuring line') devoted to the topic. Baudhayana, Apastamba and Katyayana schools developed methods of construction of squares and rectangles, relation of the diagonals to the sides, equivalence of circles with reactangles and squares in terms of area etc. The discovery of the geometrical theorem stating that the square on the diagonal of a retcangle equals the sum of the squares on the two sides in area, is usually attributed, without any justification, to the Greek Savant Pithogorus.

However, the *Satapatha Brahmana* says : "The transverse chord of a rectangle produces, by the construction of a square on itself, what the length and the breadth produce separately."

The decimal system of number, perfected later by Aryabhata was in vogue during the Vedic age. Large numbers upto 108 are referred to in many Hindu scriptures.

Medicine

The ancient Indians studied different kinds of plants and their medicinal properties. The science of medicinal plants was developed for the first time in India by Atreya, the physician and the teacher at the University of Takshashila or Taxila on the Jhelum (sixth century B.C.). His students, Jivaka (a contemporary of Buddha), Agnivesa, Bhela and Charaka, as well as Susruta of Varanasi further developed plant therapy, medicine and surgery.

The concept of *ojas* (energy), *rasa* (vital juice), *prana* (breath) affected by *tridhatu* or the three elements of fire, water and air, the bile, the mucus etc. were developed in India, and then propagated through some scientists in the Alexandria's army to Greece, who came in contact with certain Indian sages (325 B. C.) in India. Hence earlier Greek medical practice strikingly resembles the Indian system during that period.

The role of pepper, an Indian medicament, was described in the 'Diseases of women', a part of Hippocratic collection. The accounts of Megasthenes clearly reveal the Indian advancements in veterinary science during Chandragupta's reign (fourth century B.C.).

The advent of Buddhism helped the growth of Indian science, because (i) more educational institutions (such as 'Nalanda') were established (although sometimes connected with monsteries, where people pursued astronomical and mathematical studies apart from theology) in the country.

Susruta, a contemporary of Atreya, invented surgery. *Susruta-Samhita* contains description of several operations relating to cataract, hernia, caesarian (as we see today) section, plastic surgery and of several surgical instruments. The influence of his medical school on Indian science was pronounced for three centuries after Christ.

Charaka, the court physician to Kanishka (who reigned at Takshashila during the end of the first century or the beginning of the second century), compiled his medical *Samhita* on the lines of Atreya and Agnivesa. He discussed various kinds of fevers, urinary afflictions, skin diseases, epilepsy etc. He introduced logic into the critique of clinical criteria. Some of the comments found in *Charaka-Samhita* and *Susruta-Samhita* reveal an amazing degree of objective and scientific thoughts: "To gain experience in surgery *(salya-vidya)*, one has to properly dress and dissect a corpse and minutely observe the anatomical details."

Charaka and Susruta were not only experts in medicinal chemistry but also authors of several treatises on organic and inorganic compounds.

Indian 'materia medica' based on herbs and minerals was compiled by Parasara, Jatukarna, Harit, Nagarjuna (second century A.D.), Varuruchi (Kalidasa's contemporary) etc., and was well-known outside India.

Indian texts on medicine are translated into the Arabic language with the help of Harun and Mansur (715 A.D.). Harun-al-Rashid invited Indian medical experts to Baghdad and with their help he established a good hospital there.

Mathematics and Astronomy

Rig Veda describes the sun's annual course as 'twelve-spoked wheel' corresponding to the twelve signs of Zodiac. On this basis, one year was divided into twelve months, each of 30 days.

Atharva Veda refers to an intercalary thirteenth month (once in five years) to bridge the gap between the civil and tropical year.

Yajur Veda refers to twenty seven *nakshatras* (constellations) to describe the movements of the moon.

The *Satapatha Brahmana* states that one year consists of 10,8000 moments, each moment being the thirteenth part of the day.

Gradually, an elaborate lumi-solar astronomical calendar was devised and described in *Jyotisha-Vedanga* (300 B.C.).

The authors of *Rig Samhita* were accurate observers of winter and summer solstices, and solar and lunar eclipses.

Vasishtha-siddhanta, probably compiled by Vishmachandra, strove to locate celestial bodies by dividing the sky into twelve parts of 30° each. *Paulisa-siddhanta* which was written on the basis of the work by Paul of Alexandria, gave a method of determining the exact length of the day and a rough means of predicting eclipses.

Of all, the most popular and surviving system is *Surya-siddhanta* which was compiled before 400 A.D. It describes several astronomical instruments : the armillary sphere, simple gnomon, clepsydra etc. Gnomon or *canku* was described as a staff (9 inches) fixed at the centre of a circle. The shadow of the sun determined the time of the day at different seasons. A trigonometrical discussion was also furnished. Clepsydra was described as a copper vessel 4·5 inches high and of twice that width at the mouth. The vessel had a hole of a 'gold-pin diameter', and was set in a basin of pure water which entered the vessel through the hole. The extent of filling was taken as a measure of the time during day and night. The sixth part of a day, *ghati* or *ghatika* (vessel) seems to be determined from the instrument.

The *Surya-siddhanta,* the Indian meridian, was fixed at Ujjain, the then centre of astronomical research. There are discussions on equinoxes, solstics, eclipses etc. The distance between the moon and the earth was computed to be $30\frac{7}{12}$ times the diameter of the earth, The most fascinating topic in *Surya-siddhanta* is the sine table which is the oldest in the world. The concept of semi-chord (*ardha-jya* or bow string in Sanskrit) was borrowed in Arabic ***jaib*** (curve inlet) and then in mediaeval Latin *sinus* (a curve), from which the present term 'sine' emerged. There are also references to 'cosine' (*koti-jya*) and versed 'sine' (*utkarama-jya*).

Many eminent European historians accepted the fact of Indian superiroty in astronomy and mathematics during the several post-Christian centuries. Prof. J. D. Bernal, a great British scientist-cum-historian, writes in his book, *Science and History* : "There was also, and this is of the greatest importance for the whole world, a new development of science, particularly Mathematics and Astronomy, associated with the names of the two, Aryabhata and Varahamihira in the fifth century and with Brahmagupta in the seventh. ... A decisive new development was made there about this time : the perfection of a number system with place notation and a zero (Hindu number). ... The Arabs also incorporated the work of a series of Indian mathematicians on the means of dealing with unknown quantities which we call algebra."

Aryabhata, the great Indian astronomer (476 A.D.) of Pataliputra, wrote his famous book of astronomy, *Aryabhatiyam*, at the age of twenty-three, and discovered that the earth rotates round its axis. His other scientific contributions include discovery of trigonometric *sine*, accurate evaluation of π, perfection of decimal system of numbers, evaluation of A.P. and G.P. series and square and cube roots of numbers, accurate calculation of number of days in a solar year (upto seventh decimal point which is better than Ptolemy's figure), discovery of the causes of solar and lunar eclipses, prediction of duration and angular extent of eclipses etc.

Aryabhata was the pioneer to introduce the concept of *vijaganita* (algebra). He was the first and foremost mathematical genius in the world, a forerunner of Newton and others who were to be born more than thousand years later.

Varahamihira (505 A.D.) made several observations on comet. Apart from his *Pancha-siddhanta* containing five systems of astronomy, his *Brihat-Samhita* mentions about the motions and conjunctions of celestial bodies.

After Aryabhata and Varahamihira, there was remarkable advancement in Indian mathematics and astronomy due to Brahmagupta (598 A.D.) of Ujjain, who wrote the astronomical treatises: *Brahmasphuta-siddhanta* (628 A.D.) and *Khandakhadyaka* (664 A.D.). Although he was an opponent of Aryabhata's theory that the earth rotates round the sun, yet he substantially improved Aryabhata's method of astronomical calculations and computation of latitude and longitude. In his *Brahmasphuta-siddhanta* he extensively dealt with the properties of cyclic quadrilateral and trapezium and the relation between their sides, diagonals and area.

Mahavira (850 A.D.), the Jain mathematician of Mysore, was a notable commutator of Brahmagupta's theories during the nineth century. In his *Ganita-sarasamgraha* Mahavira was concerned with the properties of right-angled triangles, areas and circumferences of ellipse, geometrical progression series and so on. He used his mathematical knowledge in various calculations on excavation and shadows. Manjula (932 A.D.), the author of *Laghumanasa* and Sripati (1039 A.D.), the author of *Siddhanta-khara* further extended the concepts of Indian astronomy and mathematics.

Bhaskaracharya (1114 A.D.) was a great astronomer-mathematician in ancient India. His *Siddhanta-siromani* written in 1150 A.D., was divided into four parts : *Lilavati* (Rule of Arithmetic), *Vijaganita* (Algebra, root extraction), *Graha-ganitadhyaya* (motions of the planets), and *Goladhyaya* (Calculations of the sphere). Bhaskara advanced the concept of *Vijaganita,* and dealt on algorithm, zero and its use, unknown quantities, surds, the pulverizer or kuttaka, solution of quadratic equations and of certain equations of the third and the fourth degree.

H. T. Colebrooke, in his book *Algebra, with Arithmetic and Mensuration from the Sanskrit of Brahmagupta and Bhaskara* (London, 1817) wrote : "The points in which the Hindu Algebra appears particularly distinguished from the Greek, are, besides a better and more comprehensive algorithm, first, the amanagement of equations involving more than one unknown term, the second the resolution of equations of higher order, anticipating a modern discovery in the solution of biquadratics, third, general methods for the solution of indeterminate problem of 1st and 2nd degrees, and lastly, application of algebra to astronomical investigation and geometrical demonstration."

The full solution of the Pellian equation $ax^2+e=y^2$, and its more general form $ax^2+bx+c=y^2$ was given by Bhaskara who developed the 'cyclic' method.

The decimal notation and the use of zero have been unique Indian contributions to the world of science. The basic concept of decimal notation was known to the Indians during the time of Aryabhata.

Chemistry and Metallurgy

Indians made significant technological advances in metallurgy based on Kanada's theory of atoms and molecules (500 B.C.). Iron pillar of Delhi (fourth century A.D.), a malleable rustless metal, welded to a tapering cylinders and exceeding six tons in weight, is a remarkable tribute to the ancient Indian metallurgy. Iron pillars of Bhubaneswar (540 A.D.) and Konark (900 A.D.) have also withstood the test of time. Solid copper bolt in Ramapura Ashoka Pillar (third century B.C.), pure copper Buddha (400 A.D.) at Sultanganj, made by casting and detailed descriptions on zinc metallurgy (1200 A.D.) in Rasanava are distinct evidences of great attainments in non-ferrous metallurgy in ancient India.

Nagarjuna (700 A.D.) was an eminent authority on metallurgy and chemistry. His treatise, *Rasaratnakara* contains details on the apparatus for sublimation, distillation, extraction etc. as well as extensive uses of red sulphide of mercury *(makaradhvaja)* and black sulphide of mercury *(kajjali)*.

After the Muslim invasions of India, the Arabs and Persians benefited themselves with the boon of Indian science. In spite of unfavourable conditions created by the invaders in the country, Indian scientists did not give up scientific pursuits. During the eleventh and twelve centuries a medical school flourished at Tiruvadufarai in South India. Ganesha Daivadhya (1498 A.D.) gave reasonably accurate method for calculating the mean positions of the sun, the moon and the planets in terms of their positions on the 19th March, 1520. Nilakanta and his contemporary mathematicians (sixteenth century A.D.) derived expressions for $\mathrm{Sin}\,(A \dot{-} SA)$ and infinite series for Sin, $\cos^{A}$ and $\mathrm{Tan}^{-1}p$.

Max Muller said : "If I were asked under what sky the human mind has most fully developed some of its choicest gifts, has most deeply pondered on the greatest problems of life and has found solutions of some of them which deserve the attention even of those who have studied Plato and Kant, I should point to India."

Ancient Indian sages and seers had profound insights into what are now known as modern scientific discoveries : Goddess *Shakti* or Energy, ***Brahman*** that cannot be described in words, is the ultimate reality ; the universe vibrates etc. can perhaps be corelated with modern discoveries. They had profound insights into structure of matter, the composition of the universe and various forces operating therein. These insights were largely based on intuition and speculation.

After Bhaskaracharya in the twelfth century, Indian science did not develop remarkably till late in the eighteenth century. The revival of the study of science began thereafter.

Thus it is seen that ancient India possessed advanced knowledge in various branches of science. The texts which were originally written in Sanskrit, were later translated into Persian and Arabic after the Muslim invasion in India, and passed on to the Arabian and European countries who benefited much from the Indian scientists.

SCIENCE IN MODERN INDIA

Ancient India played an important role in the history of science and technology. It appears that some of the observations about the origin and composition of matter, as expounded by Kapil, Kanad and also by some Buddhist philosophers, are close to the modern theories. Ancient India was aware of some basic principles of 'Applied Sciences', such as astronomy, surgery and metallurgy.

In fact, modern science came to be known in India mainly during the British period. The British had superior technical skill and India her natural resources, and in India the modern scientific ideas and methods were given a proper shape during the eighteenth century.

In the middle of the eighteenth century, Raja Rammohun Roy (1774), was the first Indian who gained thorough knowledge of ancient literature in Arabic, Persian and Sanskrit, and keenly felt the uselessness of classic studies, unsupplimented by modern scientific knowledge discovered in the West. He became the dauntless crusader for the western and scientific education in India, and initiated a new chapter in Indian science.

In 1784 Sir William Jones, Judge of the Supreme Court in India, founded the Royal Asiatic Society in Calcutta. The Orientalists like Lord Hastings

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and William Jones were eager to unravel the mysteries of the Indian subcontinent — its geography, history, and culture and the trend of modern research in the country. William Jones was simply charmed to notice the prospect of scientific research in India. He was the pioneer to study the Indian plants and classify them according to the modern botanical system. Since the middle of the nineteenth century, the Society published many original articles on Zoology, Botany, Anthropology, Physics, Meteorology, Chemistry, Geology and Medical sciences, and thus played a crucial role in regeneration of science in India. The great Indian scientists like J. C. Bose, P. C. Ray, Ashutosh Mookherjee and others used the forum of the Asiatic Society to communicate to the general public, the results of their scientific investigations.

In order to enlighten the Indians, a definite improvement of educational facilities in India was an absolute necessity. Raja Rammohun Roy, with the help of certain enthusiastic Englishmen, started a few modern schools and colleges in Calcutta and other places, where modern science along with other subjects like history, geography, literature, mathematics etc. used to be taught by Indian and European teachers. His sole aim was to promote the knowledge of modern sciences among the Indian students. He forcibly pleaded for inclusion of modern science in the academic curriculum of the educational institutions. Rammohun's advocacy served as a beacon-light for the future aspiration of Indians in the realm of science.

During the twenties and thirties of the nineteenth century, most of the scientific education was imparted in the Hindu College in Calcutta. British India Society of London sent scientific equipments related to Astronomy, Optics, Chemistry and Mechanics. These equipments reached Hindu College in April, 1823. In 1827 medical classes were opened in the Calcutta Madrasa to teach the *Unani* system, and in the Sanskrit College to teach the *Ayurvedic* system. In 1828 in the Sanskrit College the students who were taught medicine and anatomy were taught to handle human body and to dissect certain animals. With the growth of science in India, scientific education in English progressed rapidly through numerous schools and colleges in India. A large number of scientific organizations were established, and educational facilities in India were put on a sound base through establishment of Universities of Calcutta, Bombay and Madras in 1857, one hundred years after the battle of Plassey (1757). Indians began to share the thoughts and aspirations of the pioneers of scientific education in the country.

In 1784 after The Asiatic Society of Bengal was started with a view to enquiring into 'Man and Nature', other societies which followed, were The Madras Literary Society and Auxilliary of the Royal Society (1833), The Agricultural Society of

India (1920), and The Bombay Natural History Society of India (1883). There were also The Trigonometrical Society (1800), The Geological Survey of India (1851), the Botanical Survey (1889), The Archeological Department (1862), and the Indian Association for the Cultivation of Science which was founded in 1876 by Dr. Mahendralal Sircar, acquired reputation as a first-rate physical research centre in the country.

Efforts were made in various ways to utilise the natural resources in India. Coal was discovered and extracted from Raniganj, petroleum from Assam and Burma, and gold from Mysore. The railways were constructed for better communication. Eminent European scientists like Lambton, Everest, and Voysey came to India, and brilliant Indians participated in the study and progress of modern science bringing a new era in the country.

Raja Rammohun Roy, with his remarkable foresight, was the first Indian to realise that the only way India could serve herself was through Western education. So he convinced the British Governor-General in India, of the need for introducing certain branches of science like Mathematics, Physics, Chemistry and Physiology in the curriculum of educational institutions for the benefit of Indian students.

Western education was soon introduced by David Hare and Rammohun Roy in Calcutta.

Hindu College was established in 1816, and later, Presidency College in 1855. The Christian Missionaries had also founded a Missionary College in Srirampore in Bengal in 1818, the Wilson School at Bombay in 1834, and the Madras Christian College at Madras in 1837. The universities at Calcutta, Bombay and Madras were established in 1857. Thus the dream of Raja Rammohun Roy for the advancement of learning in India, took a definite shape in course of time.

At the beginning of the century, the education was mainly confined to literature, logic, philosophy, history etc. Modern science was subsequently included in the curriculum at a later stage.

The first science research institute which was founded by Dr. Mahendralal Sircar (1833-1903) in 1876 without government patronage but with funds raised from the patriotic Indians, was the 'Indian Association for the Cultivation of Science' in Calcutta. Dr. Sircar was a renowned medical practitioner (Homeopath) having a fairly large income. But he felt the need of a research institute for the young Indian scientists for carrying on scientific experiments in an equipped laboratory so that they were able to develop their knowledge and experience in the said field. So he gave up his profession and devoted his life to this noble cause. He raised funds and constructed the building of a laboratory. It was named the Indian Association for the Cultivation of Science.

In 1869, Dr. Sircar wrote an article in the then well-known *Calcutta Journal of Medicine*, elaborating an idea of setting up a national institute of scientific study and research. He wrote : "We want an institute which will combine the character, the scope and objects of the *Royal Institution* of London, and of the *British Association for the Advancement of Science*. We want an institution of the masses, where lectures on scientific subjects will be systematically delivered, and not only be illustrative experiments performed by lecturers, but the audience should be invited and taught to perform them themselves. And we wish that the institution be entirely under the native management and control."

On 3 January, 1870, *Hindoo Patriot*, the legendary daily, published the prospectus and appealed for donatious. Indians donated liberally, and the IACS was founded. Its teachers included Father Lafont, Sir Jagadish Chandra Bose, Sir Ashutosh Mookherjee, Tara Prasanna Roy and many others.

But at the end of his life, Mahendralal Sircar, the founder of the IACS, was a disillusioned man who lamented that full-time teachers and researchers could not be found for the IACS for want of funds. At the 25th annual general meeting he said, "I do not know how to account for this apathy of our people towards the cultivation of science. And, therefore, I am forced to confess that I made a mistake in starting the project of founding a Science Association at all, and that I have wasted a life, as I have told you, in attempting to make it a national institution. If I had vigorously applied myself to the practice through homeopathy, I am sure I could have felt as a legacy an amount of money equal to that I have succeeded in collecting in over thirty years."

This note he wrote two years before his death on 23 February, 1904. It is a fact that Mohendralal Sircar worked throughout the best part of his life to nourish the IACS as an affectionate parent, sacrificing his personal comforts and gains. His unselfish sacrifice in the national field of service will be ever remembered by his countrymen.

Rev. Father Eugene Lafont S. J. (of the Society of Jesus) of St. Xavier's College, Calcutta, who arrived at Calcutta on 7 December, 1865, was a pioneer of Indian science. With his sincere and deligent efforts, scientific interest and thought grew in the minds of his students, one of whom was Jagadish Chandra Bose.

Father Lafont had been steadily acquiring apparatus for the Physical Laboratory of the College, and also for day-to-day meteorological observations that he had been carrying out himself, along with some of his students.

In addition to his scientific teachings in the regular classes, he used to deliver his special popular lectures in the College Hall on various scientific subjects, and continued them till his death in 1908. His scientific lectures equally fascinated the contemporary architects of scientific renaissance in

India, and even Dr. Mahendralal Sircar, the eminent Homeopath and founder of Indian Association for Cultivation of Science in Calcutta, was strongly attracted by his scientific zeal, and became tied to him by a life-long friendship.

The discourse of Father Lafont on the 'Physical Basis of Spectrum Analysis' delivered on 11 April, 1872 at the Medical College, stirred up the listeners' minds greatly in favour of propagation of science in India. *The Indian Mirror* commented inter alia on this lecture: "There can be no doubt that Father Lafont and Dr. Sircar are the persons to whom the popular vote would turn in the matter of the choice of leaders. It is to them, therefore, that all our hopes in this direction are directed."

Father Lafont used to regularly deliver lectures at the Science Association Hall, after it was founded. In 1893, the Science Association was affiliated in the Physics and Chemistry course of Calcutta University upto the First Arts standard. While in his death bed, Dr. Sircar rightly referred to Father Lafont: "......without whose ungrudging and long continued aid the Association could never have been an accomplished fact."

Father Lafont was always the first to exhibit the latest discoveries of physical science to his students: Telephone, Wireless Telegraphy (the discovery being made first by Sir Jagadish Chandra Bose, a student of Father Lafont who insisted on his celebrated student that the discovery should be demonstrated in public), X-ray, Coloured photography, Phonograph, the phenomena of Radioactivity etc.

An ardent lover of experimental science, Father Lafont (as the Rector of the College) expanded the Physical Laboratory of the College, and erected an Astronomical Observatory there. Now he wanted to erect a Spectro-telescope inside the College compound. He approached the Asiatic Society of Bengal (of which he himself was a Member) for funds, raised donations from different institutions, and finally purchased all the necessary equipments at a cost of Rs. 21,000. A magnificient circular flight of steps led to the Observatory which was placed 60 ft. above the ground. The important equipments were : a large equatorial, a parallelalistic instrument, object-glass which was furnished with an hour-circle, six astronomical eye-pieces, five micrometer eye-pieces, one ring micrometer, a clock work with conical pendulum, a direct vision Spectroscope, and a polarising helioscope with photometer. It took 18 months to complete the whole instrument. Father Lafont's astronomical work was pioneering, indeed, in India.

Besides J. C. Bose, many other Indian students were influenced by Rev. Fr. Lafont's teachings and adopted science as the main guiding principle in life. To name a few, Devendra Nath Mullick, a Physicist, Hariprasanna Chatterjee (later Swami Vijnananda of Ramakrishna Order), an engineer, P. N. Bose, a famous geologist etc.

Justice Gurudas Banerji said, "Father Lafont's mission has been to popularise the study of science in this country."

Sir Ashutosh Mookherjee remarked that Father Lafont had 'a very deep sympathy with the aspirations of educated Indians.' He also said, "The influence of Father Lafont is to be found in many of the science courses of study at Calcutta University. His name will be long kept in mind as that of one of the pioneers of scientific education in Bengal."

Many great Indian scientists emerged in India of the nineteenth century, and the foundation of modern Indian science was thus firmly laid.

Sir J. C. Bose, the Physicist, showed the path to the experimental science in the country. Acharya P. C. Ray, the Chemist, who had no family, devoted all his life to the cause of science and the welfare of his countrymen. His *History of Hindu Chemistry* discovered India's past scientific achievements. The inborn genius of Ramanujan, the Mathematician, proved his knowledge of the latest mathematical theories. And this tradition of modern science in India developed many new avenues and showed new ways to the young aspirants of the country.

Sir Ashutosh Mookherjee who integrated teaching and research at the university level for the first time in India in 1916, needed a band of teachers to set up the laboratories and to start classes for science students. The donations of Sir Tarak Nath Palit and Sir Rash Behari Ghosh, enabled him to lay the foundations of the University College of Science at 92, Upper Circular Road in Calcutta (now the road is named after Acharya P. C. Ray). The biological sciences were, however, housed at the residential building of Sir Tarak Nath Palit at Ballygunj Circular Road in Calcutta, for want of space for the purpose.

In the early twentieth century, modern science was already introduced in post-graduate courses at the Calcutta University in 1913 through the efforts of Sir Ashutosh Mookherjee. Soon three remarkable discoveries were noticed—— 'Thermal Ionisation' of Meghnad Saha, 'Bose Statistics' of Satyendra Nath Bose, and 'Raman Effect' of C. V. Raman. And Raman received the Noble Prize in 1930, by lifting Indian science to an equal level with world science.

The glorious period of science in Calcutta was between 1895 and 1937. The first year saw the first-ever transmission of wireless waves, and the second, Meghnad Saha taking over the Indian Association for Cultivation of Science (IACS) as its Secretary. Both the dates relate to Jagadish Chandra Bose who successfully transmitted wireless waves at Presidency College, and once again at the Town Hall of Calcutta in 1895, and who died in 1937. During this period, scientists in Calcutta outpaced rival experiments round the globe: Bose in regard to wireless transmission, and C. V. Raman in regard to scattering of light with an effect, which since 1930 has been named after him. Besides, there were also a few scientists of international eminence during those 42 years, especially, Prafulla Chandra Ray, Meghnad Saha, Satyen Bose and Jnan Ghosh among others.

Kedareshwar Banerjee at the Viziagram Laboratory discovered that differences in the diamagnetic susceptibility of crystals was a better and more reliable way of determining their structure than X-raying them.

In 1915 Jnan Ghosh and J. N. Mookherjee started research in Physical Chemistry, leading in 1918 to Ghosh's theory of complete dissociation of electrolytes, while S. C. Mukherjee concentrated on Colloided Chemistry.

In 1917 Upendra Brahmachari made Urea Stimabine for Kalazar. From 1923 onwards, Prasanta Mahalanobis developed statistical methods for forecasting floods and crops, and in 1956 he formulated the second Five-year Plan of the Government of India for the country's economic development.

Shyamadas Chatterjee at the Bose Institute discovered nuclear fission in 1940, but prevailed upon to refrain from publishing it. Thus Chatterjee was singularly unfortunate. On a visit to Europe, he suggested to a German scientist that refraction of *gamma* rays may be possible through medium of low temperature liquid helium. But he did not attempt it himself.

Then there was an international race in science. India did not participate in that competition. A British and a German were the main competitors. The German won and the radiation was officially named after him, 'Roentgen Ray'. But he was a modest man and preferred the term 'X-Ray'. There was another man who also preferred the term 'X-Ray'. That was the British who had lost the race by a few days. The discovery was in the same year 1895, as Jagadish Bose's demonstration of wireless, and the first Nobel Prize in physics went to Roentgen. That was one of the reasons for Bose not getting it.

The two persons to whom C. V. Raman felt deeply indebted, did not live to see the scientist getting the Nobel Prize in 1930. Mahendralal Sircar who had organised the laboratory in which Raman worked, had died in 1904 ; and Ashutosh Mookherjee who had discovered the latent in Raman, and gave him the full opportunity to carry on his research work, died in 1924. But the latter had seen Raman take the first steps in that line of research. The international race for the *Raman Effect* had begun while Mookherjee was alive, with a paper that Raman and Bidhubhusan Ray, (another contemporary of Raman) sent to the Royal Society in 1921. Two years before that, the elder scientist Mookherjee had received a monograph dedicated to him entitled *Molecular Diffraction of Light* by C. V. Raman.

When C. V. Raman's papers were published, the American, French and Russian scientists had also joined the race. The 'Effect' was discovered on 28 February, 1928 and announced in Calcutta dailies on 29 February, it being a leap year. The report was mailed to *Nature* on 8 March, and published on 31 March. On the latter date the *Indian Journal of Physics* also published the paper.

French scientists engaged in the same research, published two papers in April and seven in June. The Russian had been close to Raman, but slow in printing and their first paper appeared in print in June.

Like the Englishman who lost the race in *X-Rays*, and the Nobel Prize refusing to use the description 'Roentgen Rays', the Russians till today avoid the term 'Raman Effect'.

The two World Wars, in spite of their disastrous consequences, had also a profound effect on the scientific research in India, specially in the field of defence. It had advanced the pace of scientific research to a stage which would have taken ages to reach in normal conditions. Science and technology soon developed considerably in the country, and they were being oriented towards the benefit of mankind. Precision but more sophisticated and complex instruments came to be used with remarkable results in the field of modern science.

In later days, modern science grew to be a more organized team-work, the success of which depended on the effective co-ordination of individual efforts. The National Planning Committee formed in 1940 under the chairmanship of Jawaharlal Nehru, created greater scope for the progress of science and technology in India. During the post-independence period, Nehru successfully led the said Committee to create brighter possibilities for Indian science. Nehru fondly hoped India to acquire the scientific temper, and he gave his full support to scientific research during the post-independence period. There came in India the Green Revolution, the Atomic Energy Programme, the wonderful launching of satellites, the wide-spread use of computers and the increasing popularity of electronics, even in the field of entertainment and elsewhere.

Nehru said that the basic thing that science should do is to teach us to think straight, to act straight and not to be afraid of discarding anything or of accepting anything, provided there are sufficient reasons for doing so.

Jawaharlal Nehru believed in science as the key to human progress, as the most effective lever for the material and economic uplift of humanity. He was fully aware of the modern currents in science. He declared, "Space-time and the quantum theory utterly changed the picture of the physical world."

With his academic background in science, Nehru's early approach to the problems of life was essentially scientific. He believed with all facile optimism of early manhood that science would usher in the millennium.

Nehru had great interest, hope, and admiration for modern science. He writes in his 'The Discovery of India': "Science...made the world jump forward with a leap, built up a glittering civilization, opened up innumerable avenues for the growth of knowledge, and added to the power of men to such an extent that for the first time it was possible to concieve that man could triumph over and shape his physical environment. Man became almost a geological force, changing the face of the planet earth chemically, physically, and in many other ways ... ... Perhaps new developments in biology, psychology, and similar science, and the interpretation of biology and physics, may help man to understand and control himself more than he has done in the past."

He continues, 'The applications of science are inevitable and unavoidable for all countries and peoples to-day. But something more than its application is necessary. It is the scientific approach, the adventurous and yet critical temper of science, the search for truth and new knowledge, the refusal to accept anything without testing and trial, the capacity to change previous conclusions in the face of new evidence, the aliance on observed fact and not on pre-concieved theory, the hard discipline of the mind——all this is necessary, not merely for the application of science but for life itself and the solution of its many problems. Too many scientists today, who swear to science, forget all about it outside their particular spheres. The scientific approach and temper are, or should be, a way of life, a process of thinking, a method of acting and associating with our fellowmen. ... The scientific temper points out the way along which man should travel. It is the temper of a free man."

He also says, "Science deals with the domain of positive knowledge but the temper which it should produce goes beyond that domain. The ultimate purposes of man may be said to be to gain knowledge, to realize truth, to appreciate goodness and beauty."

Before assuming full responsibility for natural planning after 1951, Nehru was primarily a devotee of the natural science, as by training he actually was. He came to formalize himself with the more intricate economic aspects of planning, but with the same scientific temper and therefore necessarily tentative steps, only when the actual work of planning and the economy came to rest very much on him. He did not hesitate to consult experts and showed little conscious preference in choosing his advisers from different parts of the world. The experts commanded the ultra-democratic objective of local community planning, and those who would not rest without a bloated heavy-industry-based public sector. Public sector investment played a key role in ushering in the socialist pattern of the country.

Science is the architect of the modern world. Modern science has conferred many boons, whose benefits to mankind are immense in extent and comprehensive in kind. Several dreaded diseases have been conquered. Scientific achievements have made life more and more comfortable and secured.

Dr. S. Radhakrishnan says: "What is science? Science is the pursuit of truth. And what is truth? Truth is not something which you manufacture from out of the resources of your mind; it is the pursuit of something which is extramental, which is objective, which is there to which the human individual has to subscribe. All the great changes that have taken place from the time when men lived in primitive caves down to the time when we are trying to traverse regions of space—all these things are due not to mere mind or the senses but to that spirit in man."

Nehru was the chairman of the National Planning Commission and that of the National Development Council, when he was the Prime Minister of India. He drew up a programme of planned development in the field of science and technology.

The progress of technology in India has been possible due to excellent planning of the Government, which indicates some distinct phases: setting up of industry with imported machinery and know-how, teaching of teachnology, sending students abroad to receive technological training; the production of machinery in India with the help of imported tools ; and a total stoppage of import of foreign tools and machines after a stipulated period, with the follow-up of production of indigenous tools and machinery in the country.

A remarkable change came about in India because of the development of science, specially during the post-independance period. The utilization of its technological power required the total effort of many scientists working on a common problem. In free India it had to be a national effort, with brilliant scientists who had specialized in different disciplines working sometimes in a team for a common aim. With this spirit Homi Bhabha had organized modern science in India. The 'Apsara' reactor which was built as early as 1956, was a turning point in scientific development in India. It required the combined effort of a good number of Indian scientists, engineers, metallurgists and administrators to make this job a satisfactory enterprise within a stipulated time.

As regards metallurgy in those days, it may be said that Indian scientists were fully aware how to plan their research programme according to the type of materials available. Now they can, of course, make and secure the essential materials to suit their needs. Indian scientific efforts have revolutionized electronics, defence and all technology in general. India has made significant contributions to solid state physics and the availability of neutrons in large numbers from her reactors.

This development of science has touched not only the ordinary man but also the rural masses. The uses of isotopes in agriculture and medicine are typical examples. The production of new mutants to increase yield in quality and quantity has benefited the farmers. This is particularly significant with the production of groundnuts, sugar, jute etc. In medicine, the use of isotopes has helped in the diagnosis and cure of various types of cancer, for not only a large number of Indian patients but also the foreigners abroad.

Today India is considered as one of the great powers in the world, which is known to have the capability to design, build and operate nuclear power stations, to mine, process and fabricate uranium fuel elements and to reprocess the spent fuel, separate plutonium for re-use and vitrify waste for long-term storage. In technical parlance, India has mastered all facets of the nuclear fuel cycle. India has also entered the fast reactor field. In the field of research and development, in nuclear science and technology, India possesses comprehensive capabilities in all the disciplines such as physics, chemistry, metallurgy, biology and so on.

India's main achievement has been the creation of peaceful self-reliant capability in all facets of nuclear technology. India commissioned the first unit of the Madras Power Station in 1983. The Fast Breeder Test Reactor at Kalpakkam was commissioned in 1985.

Thus it is seen that scientific studies and research in India may be said to have a decisive beginning only in the twentieth century. Many eminent Indian scholars inspired generations of students by their individual achievements. With science education making headway, scientific research has also received such encouragement and assistance from the Government. Encouragement is given to both pure and applied scientific research.

Some of the new important research institutions of the country are : The Council of Scientific and Industrial Research Centres ; The Indian Council of Agricultural Research with its network of 30 national and central scientific institutions ; and the Indian Council of Medical Research with its 22 national institutions and several regional institutions. India is known to have the third largest number of scientific personnel in the world.

Science and technology from the backbone of industry and various service sectors that are required to develop and manage modern industry. The atomic energy programme and some of the other scientific programmes such as those of the Department of Space, have certainly provided opportunities to young Indian scientists and technologists to pursue their bright careers in scientific research.

It is true that scientific research is becoming more and more group-oriented. In India, this is happening in the Research Centre of the Department of Atomic Energy, in Tata Institute of Fundamental Research, in the Department of Space and so on. The atomic energy project was one of the first attempts in India, where the multidisciplinary groups started functioning and this has been found to be one of the vital reasons for its great success.

In recent times India has well-nigh made a breakthrough in many areas of science including space science, telecommunication, exploration of the ocean, and generation of atomic power for peaceful purposes. These achievements, no doubt, indicate remarkable progress of India's past scientific developments, with a daring jump into new directions.

INSAT-IB

INSAT-IB is a very sophisticated, multi-purpose satellite which was launched from Cape Canaveral, U.S.A., by *Challenger*, the American space shuttle, early in September, 1983. The latest Indian satellite occupies the geo-stationary parking space, nearly 35,887 km above the equator, south of India.

As a telecommunication satellite, INSAT-IB is expected to provide (when fully operational) over

8,000 two-way long-distance telephone circuits. It has also the capacity to provide direct satellite TV telecasting services for 8,000 sets in seven Indian States, four re-broadcast transmitters for 6,600 community TV sets, and TV expansion programme consisting of 13 high-power and 112 low-power transmitters.

Previously, the 28 TV transmitters of Doordarshan used to depend on a Soviet satellite for feed, which later on had switched over to INSAT-IB, and 42 TV transmitters have been operating at present. About 8,000 Direct Reception Sets (DRS) are deployed in selected chesters in seven states. All India Radio is also supposed to deploy 94 five-channel radio net-work terminals through the satellite.

With telecommunications, meteorology and television components, INSAT-IB is thus considered as a trend-setter in satellite design even for the developed countries which have so far only single-purpose satellites. The key facility of INSAT-IB's meterological utilization is the Meterological Data Utilization Centre (MDUC) which is responsible for the Very High Resolution Radiometer (VHRR) and Data Collection Platform (DCP), data processing, analysis and dissemination. The MDUC is located at Delhi. 20 Secondary Data Utilization Centres (SDUCs) are also functioning. 28 fixed earth stations for telecommunication operate through INSAT-IB. About 10,000 two-way telecommunication circuits are understood to operate through it.

The two important earth stations of the Oil and Natural Gas Commission (ONGC), one on an offshore platform and the other onshore for oil well operation control also function through INSAT-IB.

NUCLEAR POWER PLANTS

The Kalpakkam Nuclear Power Plant is situated near Madras. It is India's third power plant, but the first Indian designed, Indian engineered, and Indian built nuclear power plant. India's first atomic power plant came up at Tarapur in Maharashtra in 1969. The second one at Rana Pratap Sagar in Rajasthan, has two units.

The generation of electricity is one of the most important peaceful applications of atomic energy. Research and development work on the application of atomic energy is done at the Bhabha Atomic Research Centre (BARC) at Trombay, near Bombay. The Centre is the largest single scientific establishment in India.

Dr. S. Radhakrishnan correctly says: "Science is both knowledge and power. ...Science reveals to us the inexhaustible richness of the world, its unexpectedness, its wonder."

INDIAN SCIENTISTS

Among those scientists who attained international recognition by work in laboratories in Calcutta, either without, or before, having gone abroad, there are at least seven prominent names against only two who had received education in science in Europe. These two are Jagadish Chandra Bose and Prafulla Chandra Ray. A third, Prasanta Mahalanobis, had been in England for only a term or two, came home on a vacation and did not go back till he had earned an international reputation.

Among those who did not have the benefit or advantage of a foreign education were C.V. Raman, Meghnad Saha, Satyen Bose, Jnan Ghosh, K. S. Krishnan, N. R. Dhar and J. N. Mukherjee. Three of them were chemists—Ghosh, Dhar and Mukherjee, while the rest were physicists. The Calcutta School of Physics earned international fame between 1920 and 1930.

One fact should not go unnoticed that elementary physics became a compulsory subject of F.A. (later Intermediate, and now Class XII) only in 1885 in India. Next year falls the centennial of the introduction of Practicals in M.Sc. Examinations as also of the Vizianagram Laboratory at 210 Bow

Bazar Street, Calcutta. That laboratory was intimately associated with the Calcutta School of Physics, though the first major triumph was achieved at the Presidency College laboratory in Calcutta, when Jagadish Bose transmitted wireless waves in 1895. That was the first time in the world that such transmission had been effected.

C. V. Raman experimented at the Vizianagram Laboratory from 1907, and was lavish in admission of his debt to its founder Mahendralal Sircar and to Ashutosh Mookherjee who had lectured on topics in physics in the hall adjoining the laboratory between 1887 and 1892. The lecture hall had come up earlier. Sircar, Lafont and Jagadish Bose had been the others to use it.

Against this backgronnd of a late start, the achievements of the Calcutta School of Physics seem miraculous. Four strands entered the School. The earliest was the installation of an observatory at St. Xavier's in 1875 by Father Lafont. Sircar's Association for the Cultivation of Science received from the Government its premises at 210 Bow Bazar Street, Calcutta the following year, had a lecture hall by 1884 and the Vizianagram Laboratory by 1891. Jagadish Bose, a former pupil of St. Xavier's College started teaching and experimenting at Presidency College in 1885 and successfully transmitted electro-magnetic waves through solid walls ten years later.

James Maxwell in 1865 had produced the existence of electro-magnetic waves but died in 1879 before these were identified or their behaviour demonstrated. Oliver Lodge, an Englishman, in 1887-88 sought to demonstrate their existence through transmission by wires. Simultaneously, Heinrich Hertz, a German, demonstrated their existence in free space discarding wires——hence *wireless*——and published his research in 1894. The publication started an international race for Hertzian waves, the new name substituting wireless. Scientists in France, England, Germany, Russia and Italy competed. Jagadish Chandra Bose succeeded though his transmitter and receiver had to be made by a Calcutta tinker who had never worked from drawings and could not read them.

Bose took over from where Oliver Lodge had left, and reduced the waves to the level of five millimeters. The waves went without wires and unhindered by solid walls from one end of Presidency College to another. The next demonstration was at the Town Hall of Calcutta, followed by a trip to London, which was an established centre of science then. The demonstration in London was in the presence of Lord Kelvin.

Ninety-five years ago the prospects of broardcasting and bouncing waves from satellites were not there, and Bose having achieved a scientific triumph was satisfied with himself and turned to other investigations, one of which was to lead to controversy.

The uncontroversial one was pioneering solid state physics and devising a crystal receiver, the forerunner of the transistors of our time. It was so much in advance of the year 1900 when Bose's work was published that its importance was missed. More than half a century later, someone else received the Nobel Prize for an advance on the Bose original. The Nobel Prize was started in 1901, and if Ross could get for work done in 1897, Bose was entitled to it for his wireless transmission in 1895.

There was another snag. While Bose's transmission was over short distance in 1901, Marconi had been able to send Morse messages by designing the antenna over long distance where the utility of wireless lay then as a safety aid for ships at sea. Neither of them received the prize, nor did Fleming whose invention of the vacuum tube in 1904 made wireless telegraphy.

Bose was the victim of both possible racial and scientific prejudices. He was suspected of mysticism in spite of repeated assertions that the occult is only the unexplained. His lectures in Britain in 1900 on responses to electrical stimuli in organic and inorganic matter led to a controversy with leading plant physiologists. They objected to his dealing with their exclusive domain. Bose contended that physiology could be a part of physics. None had heard of biophysics then. The plant physiologists saw to it that Bose's papers accepted by the Royal Society were not published in its journal. Later, one of them contended having arrived at the findings earlier.

On Bose asking for an investigation, it was revealed that the man making the allegation had himself plagiarized from Bose's papers composed and set in type but not printed. The racial prejudice against the mysticism of the Oriental mind persisted ; the papers were not printed and Bose did not get the Nobel Prize.

Ashutosh Mookherjee who had post-graduate degree in both mathematics and physics, established the University College of Science in 1912, appointing Satyen Bose, Meghnad Saha and S. K. Mitra on its staff. In 1917, he appointed C. V. Raman to the same college. Ashutosh Mookherjee was the 'indigeneous' modern scientist having had a contribution published in the Cambridge *Messenger of Mathematics* in 1881 without having left the shores of India. A year earlier P. N. Bose was published in the *Geological Magazine*, London, but it is not known whether he had been abroad.

Meghnad Saha, who had been denied a scholarship for having participated in a political demostration against the first Partition of Bengal in 1905, made a significant contribution to astrophysics by working out an equation to determine the surface temperature of a star and the dominant element from the spectrum of the rays it emited. This famous ionisation formula was discovered in 1920.

Satyen Bose's illustrative difficulties in teaching science deserve recounting as much as paucity of laboratories being obstacles to research. In 1946, Satyen Bose was asked to teach Relativity but there was little material available in English, and so he and Meghnad Saha had to translate into English from German the paper that Einstein had written. Later, Satyen Bose formulated the statistics named after him which attained world fame. S. K. Mitra specialized in radio physics.

Even after formulation and success of ***Bose Statistics***, Satyen Bose was asked to obtain a certificate from Einstein to qualify for a professorship, for Bose lacked a doctorate. Faced with a request for a testimonial, Einstein was shocked. He wrote back : "Aren't your papers adequate ?"

Satyen Bose's reply was that the bureaucrats could not understand them which a testamonial would make sense with them.

Mahendralal Sircar died three years before C. V. Raman began his research at the Vizianagram Laboratory which Sircar had founded. Ashutosh Mookherjee too died before the award of the Noble Prize to Raman, but he did receive a monograph in 1922 by Raman and published by Calcutta University titled ***Molecular Diffraction of Light.*** It was dedicated to Ashutosh Mookerjee. That monograph contained Raman's early problems into the phenomenon which had engaged his attention since 1919. Prior to his first trip to England in 1921, the first time he journeyed outside the country, Raman and Bidhubhusan Ray had sent a paper to Royal Society on scattering of light. On the return voyage Raman was struck by the blueness of the Mediterranean, and sent out notes on the topic from Aden and Bombay. He found unsatisfactory the explanation prevalent then that the sea woed its blueness to reflecting the sky. A month later, from Calcutta a third communication followed contending that a 'layer of water 50 metres deep would scatter as much light as 8 kilometres of homogenous atmosphere; in other words, it should appear nearly as bright as the zenith sky'.

Full explanation was available on February 28, 1928. The assistant was K. S. Krishnan (later to win fame for his work on the magnetic properties of crystals), who had been a post-graduate pupil at the University College of Science, Calcutta. An international race to explain scattering of light was on, as it had been earlier for X-rays, then for electromagnetic waves, and is now for the superconductor. American, French and Russian scientists were studying the phenomenon. Earlier, Jagadish Bose had beaten his rivals, including Marconi by six years, in regard to transmission of electro-magnetic waves. There had been no Nobel Prize then.

Raman won the race on scattering of light and the Nobel Prize. The winning post was first published in an established scientific journal. Raman seems to have been aware of the competition. He announced his explanation of the scattering in Calcutta dailies the day after he completed his research. That being a leap year the dalies carried the report on February 29. The paper was sent to

Nature on March 8 by surface mail, for air services had not then begun operating. Raman delivered a lecture on it on March 16, whose text was published in the *Indian Journal of Physics* on March 31. On that very date *Nature* too carried his communication.

The French published two papers on the subject in April and seven in June. The first Russian paper appeared in June. The award of the Nobel Prize to Raman was announced in November, 1930 and ceremonially handed over on December 10.

Satyen Bose had, however, predicted that the discovery would win Raman the Nobel Prize. The Compton Effect had won the prize for its discoverer in 1923. On that occasion Raman had seen scattering of light as an optical analogue of the Compton Effect. His words were : "If this be true of X-rays, it must be true of light too." In fact, the identification of the Compton Effect was encouraging to scientists all over the world in the Twenties.

Apart from Raman and Krishnan, another scientist was working on one aspect of it at the Vizianagram Laboratory itself in the summer of 1928. That was S. Chandrasekhar who would get the Nobel Prize more than half a century later, when as a result of long residence abroad he had taken American nationality. At Calcutta, Chandrasekhar was engaged in investigating 'the Thermodynamics of the Compton Effect with reference to the interior of stars', whose results were presented as a paper to the Science Congress in January, 1929. The Nobel Prize came to Chandrasekhar on a follow-up of the research on the interior of stars done at Cambridge and presented to the Royal Society in 1937. The award was delayed because the idea of stars ceasing to emit light due to the pull of gravity from their own core took time to be accepted. Now such stars are recognized as 'black holes'.

The race for finding the equation of scattering of light, intensified by the award of the Nobel Prize to A. H. Compton, had an amusing aftermath. Just as the British prefer X-rays to Roentgen rays, because their scientist narrowly lost the race for it, the Russians avoid using the nomenclature *Raman Effect*.

Chandrasekhar came to Calcutta like Krishnan and others before him, to be in a 'creative atmosphere'. But later, he left for America and lived there.

Some of the pioneers in modern science in India, who are introduced here, contributed their might in building modern India, as we see today.

JAGADISH CHANDRA BOSE

(1858–1937)

J. C. Bose

Jagadish Chandra Bose was born on 30 November, 1858 in Mymensingh (now Bangladesh). He had his education at Calcutta, Cambridge and London. Though he studied the physical sciences in St. Xavier's College at Calcutta, he graduated in the Natural Sciences in England (B.A. from Cambridge and B. Sc. from the London University). He joined the Presidency College, Calcutta, in 1885 as Assistant Professor of Physics. Most of his physical and biophysical investigations were commenced and completed at the Presidency College.

Jagadish Chandra founded the 'Bose Institute' in November, 1917 with donations collected from the Indian people. He remained its Director till his death on 23 November, 1937.

The scientific investigations of Jagadish Chandra Bose are generally classified as follows :

1894-1899 : Production of a compact apparatus for generation of electro-magnetic waves of wave length from 22 mm to 5 mm and the study of their quasi-optical properties.

1899-1902 : Discovery of the common nature of electric response to all forms of stimulation, in animal and plant tissues as well as in some organic models.

1902-1907 : His continued efforts to devise inorganic models, of the bio-physical phenomena underlying electrical and mechanical responses to stimulation, the transmission of excitation in plant and animal tissues, and of vision and memory.

1907-1933 : Study of response phenomena in plants. Among his findings in this respect which won world-wide acclaim were : (1) Plants, like human beings, possess the power of response. (2) A plant sways abnormally like a drunkard if treated with an alcoholic substance and becomes normal when the cause is removed. (3) The roots are not the sole media for procuring food for plants. (4) Plants have nerves and they, too, feel the pain when hurt. With an instrument devised by himself, Bose showed both pain and relief are felt by plants. The feelings are transmitted through glands in the branches and the stalks of the leaves and the fruits. (5) Plant cells expand and contract like the heart in men and animals.

Among Bose's several monographs the most outstanding one is 'Response in the Living and Non-living', which was recognized by the Royal Society in London. Bose conducted his experiments to show that plants and metals have feelings, on 10 May, 1901 in the hall of the Royal Society in London, which was packed with eminent scientists. His paper was published and circulated all over the world. And Bose became a world-famous scientist. He was elected Fellow of the Royal Society in 1920. But before this, the London University awarded him the D.Sc. degree without requiring his presence for an examination, on his thesis entitled, "On the Determination of the Wave-length of Electrical Radiation by Diffraction Grating".

Bose was not only a biologist, but also a physicist. He can rightly be called the inventor of wireless telegraphy. In 1896 Guglielmo Marconi secured his first patent on wireless telegraphy. But one year before that, Bose had first demonstrated its functioning in public in 1895. He was the first in the world to fabricate the device that generated microwaves—radio waves of very short wave length. But his invention was not patented before Marconi, and hence Marconi was internationally recognized as the inventor.

An experiment was arranged early in 1895 at Presidency College. The generator was placed in the chamber of Acharya Prafulla Chandra Ray, who was then a staff member. Guarding the closed door was Father Lafont. Electric waves were released immediately with the firing of a pistol in the adjacent room of another professor. Thus a signal was sent without wires.

Another more dramatic demonstration followed at a meeting in the Town Hall in Calcutta, which was presided over by the then Lt. Governor of Bengal, Sir Alexander Mackenzie. The electric waves travelled from the lecture hall to a third room about 75 feet away, passing through three solid walls ; at the other end, they released a relay which was used to throw an iron ball, discharge a pistol or explode a small amount of gunpowder. To his instrument Bose had fixed a pole with a metal disc attached : this was his first aerial, a simple version of the high antennae of later wireless telegraphy.

Following this demonstration the Lt. Governor sanctioned a grant of Rs. 1,000 for Bose. He created a new post for Bose with better pay, greater responsibilities, and provision of reasonable time for research. Bose's task would be to build up science laboratories properly in Government colleges and to train advanced students for original research. He was made a Government-nominated Fellow of Calcutta University. The Government had also sanctioned an annual grant of Rs. 2,500 to him.

In 1896-97 Bose took a tour to England, France and Germany where he had been invited to give lecture-demonstrations. He was praised by the fellow-scientists everywhere for the compactness of his apparatus which incorporated several new features, and also for the details of experimental data produced. Bose spoke at a meeting of the British Association in Liverpool on his apparatus for studying electric waves. He also gave a lecture-demonstration at the Royal Institution on 29 January, 1897. *The Times* and *The Spectator*, the two leading journals of London, lauded the wonderful performance of the young Indian scientist, and a memorial signed by almost all the leading British scientists, including Lord Lister, President of the Royal Society, Lord Kelvin and Sir William Ramsay, urged the Secretary of State for India to establish a centre for advanced teaching and research in physics at Presidency College.

Bose also invented several sensitive instruments. His crescograph is an instrument used to measure the rate of growth of plant. Bose invented that the plants and metals have life on the basis of the electric nature of living things. When a part of the human body feels pain, nerves carry electric signals from it to the brain for information. Similarly, when a hand is to be moved, the brain communicates the order to do so by an electric signal. So also the brain, muscles and heart in an animal function on electric signals. Bose showed through his experiments that in plants there are small cells which behave in the same manner as the brain, muscle and heart, although a plant takes a longer time to response than the animals.

In 1900 Bose was invited to the International Congress of Physics held at the famous Paris

Exhibition. He read at the Congress his papers entitled 'On the Similarity of Responses in Inorganic and Living Matter'. It was his first announcement of the response to stimuli by the non-living. The audience which included eminent scientists of the time, was deeply impressed, and his paper was published with wide publicity in the *Transactions* of the Congress, as a most important achievement in the history of science. He was invited to address the Sorbonne University and the French and Zoological Societies.

In September, 1900 when Bose read an essentially similar paper before the British Association, many wondered how he came to the 'great generalisation'. The paper was published in *The Electrical*, which commented, "What investigators in Europe had been attempting with crude and clumsy apparatus, Prof. Bose has accomplished in his laboratory in Calcutta, with a pretty little set of instruments occupying no more space than an ordinary optical bench."

Bose demonstrated similarities between radiation and mechanical strain by building a 'strain-cell' in which the twist of a wire produced a current.

Bose's studies on molecular strain and recovery led him to a new photographic theory, which explained the gradual disappearance of the latent image in a photographic plate left undeveloped, as recovery from strain. He also produced photographs without light, of growth rings in a plant stem or of an *asath* leaf, making use of the radioactivity produced in them under an electric stimulus. For his 'artificial retina', another wonderful development, he found in the common lead ore galena the fullest sensitiveness to all ether waves, from electric radiation to heat and light. Bose's studies on his molecular strain and photographic theories were published by the Royal Society in London in 1902–02.

In addition to his work on building a model eye with galena crystals, Bose carried out pioneer studies on the properties of the element selenium, which changes its electrical resistance, depending on the intensity of light falling upon it. Selenium, along with germanium, is now being used in making transistors, which are replacing valve tubes in radios and other electronic equipment. The behaviour of many electronically controlled machines like rader, guided missiles and computers is now described in physiological terms, such as intelligence, receptor, feedback etc. Computers are called mechanical brains, with certain parts serving the function of memory. Some credit for early revolutionary thinking, pointing to this direction, must go to Bose.

Bose was a poet amongst scientists, a bridge-maker between the inanimate and the animate.

Father Lafont of St. Xavier's College of Calcutta, instilled in him a love for experimental physical science, and this was further nurtured under the influence of Lord Raleigh, the famous British physicist.

In fact, Bose maintained a life-long admiration for the living objects. He started learning medicine in England, before swtiching over to physics, and kept close contact with Prof. Vines, the famous botanist. During the later part of his scientific career, he diverted his attention from physics to physiology.

Scientific research on electric waves was initiated by Bose in the early nineties of the nineteenth century. The famous scientist Clarke Maxwell had suggested that light waves are of electromagnetic nature. This was verified by Hertz in 1880. The shortest electromagnetic wave obtained by Hertz was of wavelength as large as 5 metres. Marconi, Lodge etc. used electric waves of larger wavelengths. Contrasted to this, Bose produced extremely short waves (5 millimtre wave length). In May, 1895 he published his first paper, 'On the Polarisation of the Electric Ray' in the Journal of the Asiatic Society in Calcutta. A paper, 'On the Determination of the Indics of Electric Refraction' was also submitted to the Royal Society of London, through Lord Raleigh. Bose established the remarkable similarity between the electrical and the optical beams, both being amenable to reflection, refraction and polarization. He termed the electric waves as 'broken glimpses of invisible light'. A special crystal 'nemalite' was discovered which was found to polarize electric waves just as a light-beam is polarized by tourmaline. But against the advice of his well-wishers, Bose made his discoveries public and refused to claim any patent right.

The centimeter radio waves investigated by Bose, found commercial application in radar, television etc. all over the world. As early as 1895 Bose demostrated the possibility of transmission of these waves to a distance.

Bose brought considerable improvement over Hertz's detector of electric waves. He was the first scientist to use a semi-conductor crystal like galena as a self-recovering detector of electric rays (1901). In this case also, Bose did not care for the patent rights.

During 1899-1904 Bose pointed out that there exists an intimate parallelism between the response of the inorganic matter and of the living substances. He found that the curve of the fatigue of an instrument closely resembled the figurecurve of an animal tissue. His explanations were, however, much debated in England and Europe.

The numerous instances of similitude between the responses of the living and the inert encouraged Bose to take up the study of life sciences, and plant physiology, in particular. He invented 'crescograph', in which imperceptibly slow growth of plant could be magnified several million-fold and accurately recorded. He further substantiated his findings by actual demonstration before the members of the British Royal Society (1914).

Bose's 'resonant recorder' registered the speed of transmission of excitatory impulse ; the 'oscillating recorder' traced the throbbing pulsations of the telegraph plant and finally the 'death-recorder' indicated the death-throes of the plant.

The first book of Jagadish Chandra Bose recounting the results of his investigations was entitled 'Response in the Living and the Non-living'. It was hailed as a master-piece by the entire scientific world.

Bose's pioneering research activities and lecture tours in U.K. and the continent brought not only unprecedented fame to himself but also an era of glory to his motherland.

Bose's scientific career was eventually crowned with glory when he was offered the Knighthood in England, and he was elected as a Fellow of the Royal Society (1920).

Eight years after his death, a biographical note on Bose appeared in the Encyclopaedia Britannica, which inter alia mentioned that his bio-physical research was 'so much in advance of his time that its precise evaluation was not possible'.

During Bose's visit to America, *The American* journal wrote, "What is the tale of Alladin and his wonderful lamp compared to the possibilities of Dr. Bose's Crescograph ? In less than a quarter of an hour the action of fertilizers, foods, electric currents and various stimulants can be fully determined."

After visiting Paris and Stockholm, Bose faced his opponent in Germany, the distinguished plant physiologist, Prof. Haberlandt, whose theory had been upset by Bose's work. But after Bose's lecture-demonstration before a scientific audience in Berlin, the professor changed his views and paid him handsome tribute and said, "...In Prof. Bose there lives and moves that ancient Indian spirit which sees in every living organism a perceptive being endowed with sensitiveness. It is remarkable that the same old Indian spirit which has carried to its utmost limits metaphysical speculation and introspection wholly withdrawn from the world of sense......should have brought to light in its modern representative, who is our guest today, such an extraordinary developed faculty for observation and such an ecstasy in scientific experimentation."

In his Europe tour in 1923, Bose addressed at the India Office, London, a distinguished gathering including the Brtish Prime Minister Ramsay Macdonald and George Bernard Shaw, on "Phenomenon of the Growth of Plants". The vegetarian and famous playwright George Bernard Shaw shared the agony of a piece of cabbage showing violent paroxysms when 'roasted'.

At this time Bose was nominated a Member of the League of Nations Committee on Intellectual Co-operation. He visited every year from 1926 to 1929 to attend its annual meetings at Geneva.

In Paris, the great French philosopher Henri Bergson said after meeting Bose, "The dumb plants had by Bose's marvellous inventions been rendered the most eloquent witness of their hitherto unexpressed life-story. Nature has at last been forced to yield her most jealously guarded secrets."

In February, 1938 the *Modern Review* reprinted from 'Chicago Unity', an editorial written on Jagadish Chandra Bose by Reverend John Haynes Holmes: "Dr. Bose was one of the supreme scientific thinkers and researchers of the contemporary world. His studies of plant life, as poetically beautiful as they were scientifically accurate and profound, caught the attention of mankind and made his name as famous in the West as in the East. In any list of ten or twelve most distinguished scientists of the last generation, Jagadish Bose's name would not only be included but ranked high."

The Statesman wrote: "Sir Jagadish was one of the first Indians whose devotion to science attracted interest in the West."

Along with Tagore, Jagadish Chandra Bose was regarded abroad as an embodiment of the cultural renaissance of India.

ACHARYA PRAFULLA CHANDRA RAY

(1861-1944)

Prafulla Chandra Ray was born on 2 August, 1861 in a village in the district of Khulna (now in Bangladesh). He had his early education in Calcutta. His interest in chemistry was aroused by one of the teachers of the Presidency College, Calcutta. His name was Prof. Alexander Pedler. Ray took to the study of chemistry. He left for U.K. in 1882 and took his B.Sc. and D.Sc, degrees from the University of Edinburgh by 1887.

P. C. Ray

On returning to India, he was without employment for sometime, but eventually joined the Presidency College, Calcutta, as Assistant Professor of chemistry in 1887. His lectures were very interesting and attractive not only by demonstration with numerous experiments but also with important anecdotes from the lives of the great masters and pioneers in the field of science. He retired as Professor and Head of the Department of Chemistry of Presidency College in 1916. But during his tenure as a teacher, a batch of brilliant students were admitted to the Presidency College. Among them were Satyendranath Bose, Jnanendranath Ghosh, Jnanendranath Mukherjee, Meghnad Saha etc.

Rabindranath Tagore said of Acharya Prafulla Chandra Ray : "I offer my felicitation to the *Acharya* (Guru) in Prafulla Chandra, who, as such, could infuse a spirit of enquiry in his students. He not only imparted knowledge to them, but also gave himself away and by that great self-dissemination, the *Acharya* had realised his own..."

Ray showed his ability as an original research worker even before he took his M. Sc. degree. His thesis in the M. Sc. Examination was published in the 'Journal of the London Chemical Society'. When Dr. Ray read his paper before the Chemical Society in London, it created a stir in the chemical world. *Nature* wrote : "Prof. P. C. Ray has added to his success in preparing Ammonium Nitrate in a tangible form, a further accomplishment in determining the vapour of density of this very fugitive compound."

Ray subsequently published several papers. He was the first D. Sc. of the Calcutta University.

Ray had been instrumental in founding a school of chemistry. A school of illustrious chemical investigators who had the ability to keep the torch burning, emerged under the able guidance of the *Acharya*.

Ray was mainly an inorganic Chemist. Other branches of chemistry, organic and physical, were also making progress by leaps and bounds. He attended the Congress of the Universities of the British Dominions, held in London in 1912. He also attended the 250th anniversary of the Royal Society as a delegate of the Calcutta University.

After retiring from Presidency College, Ray joined the newly founded University College of Science as 'Palit Professor of Chemistry'. He presided over the Indian Science Congress in 1920. He continued his research work till he was 75 in 1936.

Ray's first success was preparation of crystalline mercurious nitrite. The study of salts of mercury engaged him for several years.

It may be noted that Ray, when he returned from Edinburgh with a D. Sc,, was moved by the plight of his countrymen. He began to wear *Khaddar* and decided to devote himself to work with a national spirit by supporting the *Swadeshi* goods. He spent very little for his personal comforts, and was generous when the question of donation for the poor came up. He took an active part in politics.

Mahatma Gandhi and G. K. Gokhale were among his friends. He found that India was rich in natural raw materials for the production of various chemicals and medicines. But the market for such commodities was a neat monopoly for foreign products. As a patriot, this acted as an added incentive for him. He wanted to try to introduce *Swadeshi* (indigeneous) products into the market.

He actively joined the non-cooperation movement and made efforts to make chemical products indigeneously for the use of his countrymen, in order to boycott the foreign products.

During his stay abroad, he noticed how applied science was being developed side by side with the study of pure science. The theories formulated through laboratory investigations, were being put to actual use in industrial productions in works and factories. As a Member of the Chemical Society, Edinburgh, Ray visited various industrial plants. At Glasgow, the Sulphuric Acid plant impressed upon him the role of Sulphuric Acid as a key material for the development of chemical industries.

In 1892, Ray started a small chemical industry in Calcutta (which later came to be known as 'Bengal Chemical and Pharmaceutical works Ltd'.) which manufactured various pharmaceutical preparations. The institution grew with time into a big organization. It started with a capital of Rs. 800 only. In 1904 the working capital was Rs. 23,500 (70 workers), and in 1963 the same being 79,95,000 (5000 workers). It opened many branches in India. It gradually switched on to various new branches of manufacture : injectules, soaps, perfumes, caffeine, strychnine, ephedrine, santonine, toilet goods, disinfectants etc. were turned out on a large scale. Drugs of various grades and qualities were not only sold in India, but exported to foreign lands.

The 'Father of Indian Chemistry' Ray was three years younger than Bose.

When Ray joined the Presidency College of Calcutta, research facilities hardly existed there. Sir Alexander Pedler, the then Principal of the college, encouraged Ray and helped him to acquire useful equipments and chemicals as required by him for research purpose.

In 1894 Ray started investigations on minerals to hunt for the missing elements in the periodic table. The discovery of mercurous nitrite was a turning point in Ray's career. Action of dilute nitric acid on mercury gave 'a yellow crystalline deposit' which was established to be the said compound. This finding was reported to the Journal of the Asiatic Society (1896). Following this publication, an unbroken series of papers on the nitrites was published in the Journal of Chemical Society, London. Ray and his pupil N. R. Dhar published a paper on the vapour density of ammonium nitrite indicating that this compound hitherto believed to be unstable, could be vapourized and its vapour-density measured. When this paper was presented before the London Chemical Society, Ramsay and Veley warmly congratulated the authors. Prof. Armstrong commented to Ray: "The way you have made yourself a master of 'nitrites' is very interesting."

Ray not only established the ancient glory of Indian science but also inspired the Indian youth in undertaking new ventures in science and technology. Under his able guidance and material help, a group of young scientists established, in addtion to 'The Bengal Chemical and Pharmaceutical Works' on 12 April, 1901, many other industrial concern like 'The Calcutta Pottery Works', 'Bengal Enamel Works' etc., which were floated mainly with Ray's inspiration and technical advice. Ray realized that scientfic research and industrial progress should go hand in hand for the national development. His School of Indian Chemists has been probably his biggest contribution to the Indian science.

Referring to Ray's lecture in London, delivered on 10 January, 1916, *Nature* commented in its 23 March issue: "The lecture consists of a brief resume of original chemical research as carried out in Bengal in the last twenty years, and an appendix with a list of 126 papers. Some of these are of very considerable value and interest, and indicate enthusiastic work on the part of this newly created school, which is mainly due to the example and work of Professor Ray himself."

Ray trained literally hundreds of students in the Presidency College, and later in the newly established Chemistry Department of the University College of Science in Calcutta. His students in their turn adopted the profession of chemical research and spread out all over the country. For example, N. R. Dhar, after completing his pioneering work on ammonium nitrite under Ray, proliferated his research activities at Allahabad. Dr. B. B. Dey initiated a school of organic and bio-chemical research in Madras. Dr. H. K. Sen proved to be an outstanding applied chemist particularly in the field of high pressure reactions and glass technology. The works on sulphuric chlorides by Naik, a Bombay University graduate, under Ray ; on conductivity of strong electrolytes, photo-chemistry and catalytic reactions by J. C. Ghosh ; on electrical double layer by J. N. Mukherjee etc. brought fame to Indian science and to Ray's School of Chemistry, in particular. Dr. S. S. Bhatnagar who did outstanding work on Magneto-chemistry had studied at Lahore under Prof. A. C. Ghosh, a student of Ray.

As a Chemist, Ray's research work was mainly concerned with mercurous nitrate and alkyl iodides and a number of chemical elements and compounds of metalic elements with sulphur derivatives. His autobiography and the book, 'History of Hindu Chemistry' are famous.

SRINIVASA RAMANUJAN

(1887-1920)

Srinivasa Ramanujan was born on 22 December, 1887 at Erode in Tamil Nadu. He went to the Town High School at Kumbakonam at the age of 10, and in 1903 he passed the Matriculation Examination creditably enough to obtain a scholarship in the Government College, Kumbakonam. Even during the school years, he took keen interest in higher mathematics. When he was 13, Ramanujan borrowed a copy of Loney's Trigonometry from a student in the degree class of the Government College, and solved all the problems.

S. Ramanujan

His preoccupation with mathematics, and scant attention to other subjects, resulted in several unsuccessful attempts at passing the then First Arts Examination of Madras University. In the meantime, he got married and it became necessary for him to find a job. In 1912, at the age of 25, he joined the Madras Port Trust as a clerk on a salary of Rs. 30 a month.

During all these years of stress, strain and semi-starvation, his interest and work in mathematics never flagged, although all that he could consult were a few outdated and second rate text-books of mathematics in local libraries.

In 1913, Prof. Godfrey Harold Hardy, the renowned Mathematician of Trinity College, Cambridge, found among the letters on his breakfast table a large, untidy envelope decorated with Indian stamps. When he opened it, he found some sheets of paper on which in a non-English holograph, there were line after line of symbols. Hardy glanced at them without any enthusiasm. He was by that time, at the age of thirty-six, a world-famous Mathematician. He was accustomed to receiving manuscripts from strangers on various subjects. He once again glanced at the Indian letter written in halting English, signed by an unknown Indian, asking him to give an opinion on those mathematical discoveries. The script appeared to consist of theorems, most of them wild or fantastic looking, one or two already well-known but laid out as though they were original. There were no proofs of any kind. Hardy felt irritated, as it seemed like a curious kind of fraud. He put the manuscript aside, and went on his day's routine.

But Hardy could not somehow concentrate on his usual time-table on the day. At the back of his mind, there appeared frequently the untidy Indian manuscript which was full of wild theorems such as he had never seen before nor imagined. He felt that he must have some discussion with a competent Mathematician before throwing away the Indian letter. He discussed the matter with Prof. J. E. Littlewood, his close associate in the University. Before midnight, both of them knew for certain, that the writer of those manuscripts was not only a man of extraordinary genius, but also a Mathematician in the class of Gauss and Lionhard Euler. Hardy immediately made up his mind that Ramanujan must soon be brought to England.

Meanwhile, Ramanujan's friends secured for him initially a research scholarship of Rs. 75 a month on 1 May, 1913 at the Madras University. In April, 1914 he was invited to Cambridge where he joined Trinity College. In Cambridge, Ramanujan did work on 'Number Theory' and for his valuable contribution, he was elected Fellow of Trinity College on 18 October, 1917. Next February, he was elected to Fellowship of the Royal Society of London.

No account of Ramanujan is complete without a reference to the remarkably fruitful partnership he had with Professor Godfrey Harold Hardy, with whom he collaborated for five years at Cambridge. Had there been no Hardy, there would perhaps be no Ramanujan. Both Hardy and Ramanujan shared a fascination with numbers.

Once Ramanujan fell sick, as he contracted T.B. He was in a hospital bed. Hardy came to see him. He asked Ramanujan, "How are you ?"

: Better, thank you !

: The number of the taxi-cab, in which I have come here is 1729. The number seems to be a dull one, and I hope it is not an unfavourable omen.

The genius in the patient shone with a sparkle in his eyes, and he immediately replied : "No, Hardy ! It is a very interesting number. It is the smallest number expressible as the sum of two cubes in two different ways—
$1729 = 12^3 + 1^3 = 10^3 + 9^3$.

Prof. Hardy was simply amazed as to how a person almost in his death-bed, could be so active mentally. Once Prof. Littlewood remarked : "Every positive integer was one of Ramanujan's personal friends."

Ramanujan returned to India in March, 1919 at the advice of the attending doctor. He was treated at several places, but his health did not show any sign of improvement. He died in Madras on 26 April, 1920. Thus his life was cut off when he was just 33.

Ramanujan was a master of theory of numbers. The most outstanding of his contributions was his formula for *p(n)*, the number of 'partitions' of 'n'. Hardy wrote about Ramanujan's work : "Opinions may differ as to the importance of Ramanujan's work, the kind of standard by which it should be judged and the influence which it is likely to have on the Mathematics of the future. One gift it has, which no one can deny, profound and invincible originality."

In its obituary note the *London Times* observed : "There is something peculiarly sad in the spectacle of genius dying young, dying with the first sweets of recognition and success tasted, but before the full recognition of the powers that lie within."

Ramanujan was born to a tradition. There was in India, for more than six centuries before him, no tradition of mathematical research. The last great mathematician was Bhaskaracharya (circa 1114–1185).

Even many mathematically educated people are actually unable to say what exactly it was in Ramanujan's mathematical output that made him, in some sense, one of the greatest mathematicians of modern times. The difficulty lies, perhaps, in the fact that Ramanujan's mathematics was not of the conventional type—it was unorthodox and to a certain extent, weird. Rigorous proof is the very breath of conventional mathematics, but 'proof' is conspicuously absent throughout Ramanujan's mathematics. The really astonishing thing about his mathematics is a strange, raw legacy of about 4,000 conjectures, brilliant, beautiful, testifying to an intuition of an incredibly high order. It is intuition that 'worked in analogies to an astonishing extent by empirical induction from particular numerical cases'.

Ramanujan showed startling promise as a mathematician even in his childhood. He had contributed original research papers on the theory of numbers, Rilmann's Zeta function, mock theta function, modular equations, theories of continued fractions, elliptic function etc.

Some of the power and originality of Ramanujan's mathematics was understood a few years before his death. His contemporaries saw from the conjectures scrawled across pages that he possessed a genius for calculating the laws and relationships that govern the wilderness of numbers, and that he worked in a way of his own, drawing his conjectures from a mental landscape that was far away from the frontier of mainstream mathematics. Ramanujan worked in a style that awes and frustrates modern mathematics. He used a slate, jotting down formulas, and then recording a result in his Notebook when it reached the final form. Thus the intermediate results, the links, are lost, and it appears that the task of finding out such missing links lies with the future generations of mathematicians.

Ramanujan has left three precious Notebooks with his mathematical ideas scrawled across their pages. It is unfortunate to mention that though the said Notebooks of Ramanujan were with the Madras University for more than three decades, there was no effort to publish them. It was not until 1957 that the Tata Institute of Fundamental Research, Bombay, published facsimile editions of the Notebooks and made them available to the mathematical community. Since then the mathematicians have scanned, analysed and commented on many of the contents of the Notebooks which have proved to be a storehouse of problems, conjectures and suggestions that seem to have kept mathematicians busy for the past three decades.

CHANDRASEKHAR VENKATA RAMAN

(1888–1970)

Chandrasekhar Venkata Raman was born on 7 November, 1888 at Ayyanpettai in Tamil Nadu. He had his early education at Visakhapatnam and college education in Madras. He completed his school education at the age of 12. After he took his M. A. Degree in physics in 1907, he appeared at the Financial Civil Service competitive examination and, having topped the list of condidates, was appointed Deputy Accountant General in Calcutta in June 1907.

C. V. Raman

In 1917, when Raman was 29, Sir Ashutosh Mookherjee offered him the post of the Palit Professor of Physics at the Calcutta University. In 1919, he was elected Secretary of the Indian Association for the Cultivation of Science and in 1922, was awarded D. Sc. by the Calcutta University.

In 1924 Raman was elected Fellow of Royal Society for his contributions to optics.

His long years of research culminated in the discovery of the 'Raman Effect' in 1928. After

15 year's service at the Calcutta University, Raman shifted to Bangalore in 1933 to become the Director of the Indian Institute of Science.

In 1943 Raman founded his own institute near Bangalore, the Raman Research Institute, where he continued to work till his last day.

Honour came to Raman from different quarters of the world. He was Knighted by the British Government in 1929, and the Noble Prize was awarded to him in 1930. He was conferred the highest title of 'Bharat Ratna' in 1954. Raman passed away on 21 November, 1970.

The 'Raman Effect' was a demonstration of the 'collision' effect of light bullets (photons) passing through a transparent medium, whether solid, liquid or gaseous. The phenomenen takes place when molecules of the medium scatter light energy particles 'photons'. For example, when a beam of light passes through liquid benezene, it may either pass through the unseen inter-molecular gaps of the liquid without a close encounter with any molecule of benezene or 'collide' headlong with a molecule of benezene. This collision results either in the loss of energy or gain of energy.

'Raman Effect' has helped in deeper understanding of the interior structure of molecules and atoms, and thereby led to the development of industries, such as colour photography, plastics and synthetic rubber.

Raman devoted much time to the study of synthetic diamonds (leading to new knowledge about X-rays) and musical instruments.

Raman's publications include 'Molecular Diffraction of Light', Mechanical Theory of Bowed Strings and Diffraction of X-rays', 'Theories of Musical Instruments' etc.

With IACS

On an August morning in 1907, when a revolutionary emotion of Swadeshi and Swaraj grew among the youth of India, a Tamil youth named Chandrasekhar Venkata Raman, 19 years of age, travelled in a tram car down Calcutta's Bowbazar Street (now called Bepin Behari Ganguly Street), and suddenly his eyes lit up as he noticed a signboard that read 'Indian Association for the Cultivation of Science' at 210, Bowbazar Street. He rushed out of the tram car, went into the building and enrolled himself as a member then and there. Raman began his scientific research in Calcutta, that was to win him later the Nobel Prize in 1930.

Raman is the only Indian Physicist to have received the Nobel Prize. In this context, one can not but remember the principles spelt out by the founder of the 'Indian Association for the Cultivation of Science', Mahendralal Sircar.

After Sircar's death, C. V. Raman gave leadership to his mission, taking over the mantle of the founder with his indegenous capability and even technical innovation. Incidentally, the room in which Raman sat at the Indian Institute of Science had only one portrait—that of Sri Jagadish Chandra Bose.

Raman conducted pioneering research in musical acoustics, particularly on *Tamboura,* the well-known Indian musical instrument. This work made him famous. He was invited by the German Physical Society to contribute an article on the theory of musical instruments for the Encyclopaedia of Contemporary Physics (Handbuch der Physik).

The scientists around Raman were all great men. Krishnan would have been the pioneer in semi-conductors that ushered in a new era in solid state physics. He was near the point of discovery, but those were the days of World War, and there was a bomb scare in Calcutta. Krishnan had to leave the city and his research data on crystal magnetism went astray.

Kedareswar Banerjee, Krishnan's seccessor, was gratefully remembered by Hauptman in his Nobel Prize oration in 1985, as pace-setter in X-ray crystallography and his work that fetched him the Nobel Prize.

Had Raman not come to Calcutta, and had Sir Ashutosh Mookherjee, with his uncanny instinct for identifying talent, not got the opportunity to choose him to be the first 'Palit Professor of Physics' to the University of Calcutta (although the other contenders had D.Sc./D. Phil. from foreign universities against Raman's simple M.A.), the youthful scientific talent could hardly have blossomed into one of India's versatile scientists.

Sir Ashutosh Mookherjee, the Vice-Chancellor of the Calcutta University, observed in March, 1914:

"For the chair of Physics created by Sir Taraknath Palit, we have been fortunate enough to secure the services of Mr. Chandrasekhar Venkata Raman, who has greatly distinguished himself and acquired a European fame by his brilliant research in the domain of Physical Science, assiduously carried on under the most adverse circumstances amidst the distraction of pressing official duties.

I shall fail in my duty if I were to restrain myself in my expression of the genuine admiration I feel for the courage and spirit of self-sacrifice with which Mr. Raman has decided to exchange a lucrative official appointment for University Professorship, which, I regret to say, does not carry even liberal emoluments. This one instance encourages me to entertain the hope that there will be no lack of seekers after truth in the Temple of Knowledge which it is our ambition to errect."

Dr. S. Radhakrishnan said about Raman: "Dr. Raman is a great teacher. His knowledge is not confined to physical science. In this over-specialised world his breadth of knowledge is remarkable.

He combines highest intellectual integrity with a winning warmth of heart. His latter feature sometimes comes out of his utterances which are delightfully free and frank. He is our most illustrious scientist, and we fervently hope that he will continue for many years to guide the scientific progress of India."

Raman Effect

'Raman Effect' opened up the unknown routes to unveil the mysteries of light-wave optics, acoustics, colloids, and so on. *Raman Spectroscopy* now finds applications in almost every branch of scientific research. The various disciplines of *Raman Spectroscopy* represent biological systems, solid state systems, semi-conductors and supraconductors, time-solved Raman Spectroscopy, high resolution Raman Spectroscopy, non-linear Raman Spectroscopy, New Raman techniques and Raman theory. Now-a-days many world-famous scientists follow and work on these disciplines.

Professor C.K.N. Patel of Murray Hill, U.S.A., is one of the pioneers who helped open new vistas of the 'Raman Theory' following the discovery and widespread use of Laser (light application by stimulated emission of radiation). S. C. Banerjee, Professor of Spectroscopy, IACS, says, "But for the Laser technology, the vast potentials of 'Raman Effect' and its revolutionary uses in almost all the major areas of scientific research and technological breakthrough could not be imagined.

Non-polan molecules, like oxygen and hydrogen, polychromatic light and the like had to be left out for four decades since the discovery of 'Raman Effect' in the 1920s. The researchers were convinced of the penetrability of Raman Theory in solving many problems, but the technological push was missing. Infra-red spectroscopy was superior in practice to *Raman Spectroscopy*. But everything changed with the Laser."

C.K.N. Patel and his associates at the Bell Telephone Laboratories, U. S. A. developed spin-flip 'Raman Laser'. There came along the stimulated 'Raman Lasers', polarization lasers, stimulated electronic Raman scattering lasers and the rest. The new disciplines that emerged are coherent stokes of Raman Spectroscopy (CSRS), Coherent anti-stokes Raman Spectroscopy (CARAS), Raman-induced Kerr Effects (RIKES), Higher Order Raman Excitation Studies (Norses), Time-resolved Raman Spectroscopy etc.

What is, in a nutshell, 'Raman Effect'? The renowned physicist Smekal had predicted on the basis of the particular nature of light that when a light photon meets a molecule like benzene, it may emerge with some loss or gain of energy, this energy being imparted to or abstracted from the molecule. Raman observed that when monochromatic light glides through a transparent medium, some of the light gets scattered. Now, if the spectrum of this scattered light is examined, it is found, as Raman observed, that apart from the light of the original wave length, there are weaker lines which differ in wave lengths by constant amounts.

These weaker lines are 'Raman Lines' which are, owing to loss or gain of energy, experienced by photons of light due, in turn, to inter-action with the vibrating molecules of the medium in question. Raman made this discovery in February, 1928 in the laboratory of IACS in Calcutta. And that fetched him the Nobel Prize in Physics in 1930.

The discovery not only proved Smekal's hypothesis but also laid the basis of understanding of the energy levels and structure of atoms and molecules.

After the breakthrough, by way of building the first ruby laser by T. H. Maiman of Stanford University, U.S.A. in 1960, the new possibilities of applying the 'Raman Effect' opened up. Two other U. S. Scientists, J. Porto and R. W. Wood of the Johns Hopkins University, came out with the first laser Raman spectrum. It was like the outburst of a turbulent river from a glacier.

'Stokes Lines' are those that gain energy during molecular scattering, while those that lose are anti-Stokes lines. When photons collide inelastically with the molecules, they either gain or lose energy, according to the Quantum Theory. Both the Stokes and anti-Stokes lines are weak Raman Spectral lines. The laser raises intensity of the lines and makes it feasible for any single line to assume very high intensities, thereby widening the scope of 'Raman Effect'.

During his research work at the IACS, Raman built around himself a galaxy of scientists, such as Professor K. S. Krishnan, K. Banerjee, S. Bhagavantam, K. R. Ramanathan, S. C. Sirkar, L. A. Ramdas and S. K. Mitra. Many of them played their significant part in the discovery.

Lord Raleigh held the view that the blue colour of the sky originated from scattering of sunlight by molecules in the atmosphere. Raman contested this theory in his two papers published in *Nature* (1921) and *Proceedings of Royal Society* (1921), arguing that the molecularly scattered light was the cause for the blue colour of sea-water. That was a step towards his discovery.

In 1925 Ramanathan argued in a paper that there was some secondary radiation in the light scattered by certain liquids, in which the depolarization of scattered radiation varied with the wave-length of the incident radiation. Further advances were made through research by Krishnan, Venkateswaran and others and finally, the breakthrough came.

A phenomenon was studied using a quartz mercury lamp as a powerful and convenient source of excitation, there having been the advantage of the presence of a few intense, separated and nearly monochromatic wave-lengths. The scattered radiation was photographed with a portable Hilger quartz spectograph. The incident radiation was confirmed, and 'Raman Effect' was born.

At the time of receiving the Nobel Prize in Stockholm, Raman said : "The universality of the phenomenon, the convenience of the experimental technique and the simplicity of the spectra obtained, enable the effect of a wide range of problems in physics and chemistry."

Today the application of Raman Spectroscopy to medical diagnosis, interfacial analysis, optical fibres and microbes have become widespread to the extent that Raman might not have expected. It is such an important tool of percieving the molecular structure (its geometry) and distribution that there is hardly any branch of physics, chemistry, medicine, biology and astronomy that has not found it useful.

BIRBAL SAHNI

(1891-1949)

Birbal Sahni who was born on 14 November, 1891 at Bhera in Punjab, is known as the 'Father of Indian Palaeobotany'. He took up research work on ferns, conifers and fossil plants under the guidance of a renowned Botanist named A. C. Steward. Palaeobotany (the study of plants) which was then a new branch of science in India, is a subject which requires knowledge of botany as well as geology.

Sahni's father was a teacher of chemistry. After graduating from Punjab University (Lahore) in 1911, Sahni went to England and there he obtained in 1929, his D. Sc., from cambridge University. In 1936 he was elected Fellow of the Royal Society. He made remarkable discovery of a new group of gymnosperms (fossil plants—conifers and their allies—which he obtained from Rajmahal Hills in Bihar) called *pentoxyleae*, which had drawn world attention.

Besides palaeobotany, Sahni was deeply interested in archaeology. He discovered coin moulds in Rohtak in 1936, and his book, *Technique of Casting Coins in Ancient India*, fetched him in 1945, the 'Nelson Wright Medal' of the 'Numismatic Society of India'.

Sahni was the first teacher who raised the standard of teaching at the department of Botany. He established the Department of Geology. Sahni is perhaps the only Palaeobotanist of eminance India has produced. He was the head of the Botany Department of Lucknow University. ***The Gondwana Flora*** and the problem of the age of the ***Saline Series of the Salt Range*** were among the more important studies by him.

In 1949, Sahni died, a week after Jawaharlal Nehru laid the foundation stone of the building of Birbal Sahni Institute of Palaeobotany, an institute being the first of its kind in the world.

MEGHNAD SAHA

(1893–1956)

Meghnad Saha was born on 6 October, 1893 in a village named Seoratali in Dacca (now in Bangladesh). Meghnad was the fifth of the eight children of Jagannath Saha who had a meagre income from his petty shop-keeping business. So Meghnad had an uphill task in educating himself. He earned his living by giving tuition, cycling to distant places, morning and evening, to teach his students.

M. N. Saha

Meghnad appeared at the I. Sc. Examination held by Calcutta University, from Dacca College (now in Bangladesh), in 1911, and stood 'Second', the 'First' position having been secured by another brilliant student of his time, Satyendra Nath Bose. Then he came to join the B. Sc. classes in Presidency College, Calcutta, where he met Satyen as his classmate.

In the B. Sc. and the M. Sc. Examination also the same results were repeated—Satyen stood 'First', and Meghnad 'Second' in order of merit, in the years 1913 and 1915 respectively.

In Presidency College, Calcutta, Meghnad was taught by eminent teachers like J. C. Bose and P.C. Ray. He had also brilliant contemporaries like S. N. Bose and P. C. Mahalanobis, who became noted Indian scientists in later years.

Saha passed his M. Sc. in Applied Mathematics. In 1916 he was appointed lecturer in the Applied Mathematics Department of the University College of Science in Calcutta. He was later transferred to the Department of Physics, even though his formal training in Physics was upto the B. Sc. level. He studied at home the available books and periodicals and carried on his teaching.

He knew that there were dependable books available in German language on modern science. He learnt German to study such books and periodicals. He and his colleague Satyen Bose became friendly with German Professor named P. J. Bruhl who taught Botany at the Bengal Engineering College in Sibpur, Howrah in Bengal. Mr. Bruhl, due to his ill health, changed over to Physics, as he was not able to attend outdoor classes in Botany. He helped both Saha and Bose by supplying the advanced text-books in Physics written in German language. Some of the books were written by the eminent Physicist Max Planck. Both the friends divided the books between them and studied them. Saha specialized in thermo-dynamics and statistical mechanics and was able to contribute his theory of thermal ionisation which explained the physical conditions in steller bodies.

Saha had to study many new subjects in order to teach his post-graduate students of physics, and among them were thermo-dynamics and spectroscopy. His study of these subjects, as also the quantum theory of atoms, paved the way for his 'epochal work' on thermal ionisation of elements.

Saha possessed nationalistic outlook from his early years. In his school days he and some of his friends, boycotted school when the British Governor of Bengal visited the school. This made him lose his scholarship and he joined another school. He was associated with Subhas Chandra Bose and Rajendra Prasad, and as a very young student he worked as a true patriot.

Saha spent two years (1917–19) in Europe, doing research in 'thermal ionisation'. On his return, he joined the Calcutta University as 'Khaira Professor of Physics'. In 1923 he joined the University of Allahabad and remained there for 15 years. He initiated and organized research in several subjects, such as statistical mechanics, atomic and molecular spectroscopy, thermal ionisation and 'electron affinity' of electro-negative elements, active modification of nitrogern, high temperature dissociation of molecules and ionosperic propagation of radio waves and physics of the upper atmosphere.

In 1927 Saha was elected Fellow of the Royal Society, London. In 1938 he succeeded D.M. Bose as the 'Palit Professor of Physics' at the Calcutta University. Now his research was concerned with the systematics of atomic nuclei, particularly beta-activity, the propagation of electro-magnetic waves in ionosphere, and the problem of the solar corona. Realizing the importance of nuclear physics, Saha wanted to found an Institute of Nuclear Physics in Calcutta. His ambition was fulfilled. The foundation stone of the Institute was laid by Dr. Shyamaprasad Mukherjee in 1948. Saha became the Honorary Director of the Institute of Nuclear Physics, while he was the head of the Palit Laboratory of the Pure Physics Department. The Institute was, however, run by an independent governing body. He continued as the Honorary Director of the Institute till his death on 16 February, 1956.

Saha was a member of the University Education Committee appointed by the Government of India in 1948 under the Chairmanship of Dr. S. Radhakrishnan. He was also the Chairman of the Calendar Reform Committee.

As regards the phenomenon of stellar spectra, Saha suggested that at the very high temperature of the order of 6000°C or more prevailing in stellar atmosphere, many of the constituent atoms of a star must be truncated with a good many of their outer satellite electrons torn off. This process of atomic truncation, with loss of satellite electrons, is called ionisation and the truncated atom 'ion'. Stellar atmospheres were thus merely gaseous mixtures of freed electrons and atoms.

Thus Saha cleared the mystery of the stellar atmosphere by his equation relating to high temperature ionisation, i.e., loss of satellite electrons from the atoms of a star.

Saha's epoch-making equation relating to stellar spectra has been aptly termed as 'one of India's most precious gifts to world science'.

Saha's equation modified later by Fowler, Milne etc. embodies his original quantitative approach correlating the degree of ionisation with the temperature and pressure in a given stellar system.

Saha was an advocate of the strategy of development of basic or heavy industries, and was impatient to see India set on the path of progress and prosperity. In doing so, he was highly critical of private enterprises and the democratic processes. This lent substance to the view that he was a Marxist or at any rate, a fellow-traveller.

Professor Saha was elected a Member of the Indian Parliament from Calcutta constituency during 1952-56. Saha, though entirely a self-taught genius, was a bright example of the nineteenth century ideal of the complete man. Apart from his own subject, he had profound interest in history, archeology, control of rivers and industrialization. The reform of the Hindu calender was done through his efforts alone. In national planning, in river control, and in various other projects taken up by the Government of India during the post-independence period, he was the main architect. He wrote profusely on the need for industrialization in the country, on the methods of maximum utilization of cultivable land and various other essential projects.

Among Professor Meghnad Saha's publications, 'A Treatise on the Theory of Relativity', and 'A Treatise on Modern Physics' are notable. He founded and edited a magazine, ***Science & Culture,*** which carried many new aspects of modern science.

Saha was the chief architect of river planning in India. His acute concern for the socio-economic upliftment of the country led him to politics and lasted till his death in 1956.

PRASANTA CHANDRA MAHALANOBIS
(1893–1972)

Prasanta Chandra Mahalanobis was born on 29 June, 1893. He took his B.Sc. (Hon.) from the Calcutta University and M.A. from Cambridge. He became Professor of Physics at the Calcutta University in 1915 and continued there till 1947 (as Head of the Department of Statistics during 1945–1947). He became Honorary Statistical Adviser of the Government of India in 1949 and a member of the Planning Commission in 1955. He was the author of the Plan-frame which spelt out the strategy for the second Plan.

P. C. Mahalanobis

In the field of statistics, his major contributions are: 'distance' and large-scale sample surveys. In planning, he developed two-sector and four-sector models of development, for determining optimum investments. He gave an impetus to operational research in planning. He presided over the Indian Science Congress in 1950. He was mainly responsible for the development of the Indian Statistical Institute, Calcutta.

Mahalanobis was the first Indian Stastician to receive world recognition. Statistics is a subject which deals with numbers, which may have a relationship with one another or change in different situations. But using statistical methods, a conclusion or conclusions can be inferred from the numbers. Mahalanobis also tried his hard at problems in subjects like anthropology, epidemiology, demography and meteorology, which again deal with a mass of numbers. His contributions to statistics are of great importance. He was elected Fellow of the Royal Society in 1945 for his original work in the field of statistics. He invented tools like the ones called 'Mahalanobis Distance' and 'Fractile Graphical Analysis' which have wide applications.

Mahalanobis died in 1972.

SATYENDRA NATH BOSE
(1894-1974)

Satyendra Nath Bose was born in Calcutta on 1 January, 1894. Both his grandfather Ambika Charan and father Surendra Nath had English education and held government jobs. Their ancestral home was in Nadia. His mother's name was Amodini Devi.

S. N. Bose

Satyen was sent to school at the age of five. He had an inborn talent. In spite of his weak eye, Satyen was a voracious reader since his childhood. Apart from working out all the sums from the prescribed textbooks, he would solve more sums from subsidiary text-books. It was also his practice to try them by diverse methods. His genius as a wizard in numbers, was noticed by his teachers during his early years. He stood 'Fifth' in order of merit in the Entrance Examination of the Calcutta University, held in 1909.

Satyen was very well in Sanskrit, History and Geography, but he opted for the science course and joined the Intermediate classes at the Presidency College, Calcutta. In those years, in Presidency College there was a galaxy of brilliant teachers : Sir

P. C. Ray in Chemistry, Sir J. C. Bose in Physics, C. E. Cullis in Mathematics, Manmohan Ghosh (younger brother of Sri Aurobindo) in English, and many other scholars.

Satyen had taken Philosophy as his 'fourth' subject in the I. Sc. In that subject he had secured cent per cent marks, and in English the highest marks. In his I.Sc. Examination held in 1911 by the Calcutta University. Satyen stood 'First' in order of merit, and Meghnad Saha who appeared from Dacca College (now in Bangladesh), secured the 'Second' position. Meghnad joined the B. Sc. classes with Satyen in the Presidency College, Calcutta. There they became good friends.

Now in the B. Sc. Examination held in 1913 Satyen again stood 'First', and Meghnad 'Second', in order of merit. The same result was repeated in the M. Sc. (Mixed Mathematics) Examination held in 1915.

Satyendra Nath Bose and Meghnad Saha were both appointed lecturers in 'Applied Mathematics' department of the University College of Science in Calcutta in 1916 by Sir Ashutosh Mookerjee. After some time both of them were, however, transferred to the department of Physics, even though their formal training in Physics was upto the B. Sc. level. So both of them began to study modern Physics on their own. They learnt German language and studied the new concepts in the subject : the quantum theory, the theory of relativity, and Bohr's theory of the hydrogen spectrum, and all these heralded a new age in Physics in India, by giving the M. Sc. course a modern and progressive touch. Bose and Saha who were entirely self-taught in Physics, were anxious to get new books and periodicals on the subject. P.J. Bruhl, a German Professor in the Bengal Engineering College at Sibpur, Howrah, was a helpful friend of both Bose and Saha. He supplied them all the advanced textbooks in Physics written in German language. Some of the books were written by the famous scientist named Max Planck. As both of them had learnt German, they divided the subjects between them. Bose was to specialize on the 'theories of electromagnetism and relativity', while Saha on that of 'thermodynamics'. And Bose's fundamental contribution to the world of Physics is his 'Bose Statistics' which still plays a vital role in the study of modern Physics, in the field of elementary particles and in the field of super-conductivity, and Saha's theory of 'thermal ionisation', which explained the physical condition in steller bodies and which is considered one of the then major discoveries in astro-physics.

Bose's first research paper on 'The Influence of the Finite Volume of Molecules on the Equation of State' was written jointly with Saha. The physical behaviour of actual gases differs from the ideal gases which are so named, because some ideal properties are hypothetically assigned to them for the sake of simplicity. This paper was published in the *Philosophical Magazine* of London in 1918.

Boes's next papers were published in the *Bulletin of the Calcutta Mathematical Society* in 1919 and 1920. They were 'The Stress Equations of Equilibrium' and 'The Horpol Hode'. Both these papers were based on mathematical problems.

Bose's another important paper, 'On the Deduction of Rydberg's Law from the Quantum Theory of Spectral Emission' was published in the *Philosophical Magazine* of London in 1920.

Then, Bose in collaboration with Saha, translated Einstein's papers on the theory of relativity from the original German. The book which was published by the Calcutta University, happens to be the first English version of those celebrated German papers.

In 1921 Bose joined the Dacca University where he was offered a Readership.

Max Planck, the German Physicist, who ushered in the age of modern Physics, founded his quantum theory in 1900, which explains that energy is released in the form of quanta, and in packets rather than in a continuous manner. He introduced his formula $E=h\nu$. Bose studied Planck's *Thermodynamik und Warmestrahlung* on the distribution of energy from a black body based on this new theory. To Bose this theory seemed to be an ad hoc assumption. Three years later, in 1924, his paper 'Planck's Law and Light Quantum Hypothesis' was published in the German scientific journal *Zeitschrift fuer Physik*, which won him fame overnight. Bose had also communicated this paper to the *Philosophical Magazine* and sent a copy of it to Einstein requesting for his comments.

While doing so, Bose wrote his first letter to Einstein as below :

Physics Department
Dacca University
Dated the 4th June, 1924

Respected Sir,

I have ventured to send you the accompanying article for your perusal and opinion. I am anxious to know what you think of it. You will see that I have tried to deduce the coefficient $\frac{\pi v^2}{c^3}$ in Planck's laws independent of the classical electrodynamics only assuming that the ultimate elementary regions in the Phase space had the content h^3. I do not know sufficient German to translate the paper. If you think the paper worth publication, I shall be grateful if you arrange for its publication in *Zeitschrift fuer Physik*. Though a complete stranger to you, I do not feel any hesitation in making such a request. Because we are all your pupils though profiting only by your teachings through your writings. I do not know whether you still remember that somebody from Calcutta asked your permission to translate your papers on Relativity in English. You acceded to the request. The book has since been published. I was the one who translated your paper 'Generalised Relativity'.

Yours faithfully,
sd/– **S. N. Bose**

The paper was duly translated by Einstein and published with the translator's remarks: "In my opinion Bose's derivation of the Planck formula signifies an important development. The method considered here yields also the quantum theory of ideal gases which I shall discuss elsewhere."

With this work the name of Einstein has been linked with that of Bose and the young Indian scientist made his first entry into the field of international science. The salient features of the paper appeared to be of fundamental importance in the later half of the nineteenth century. The spectral distribution of radiation emerging from a small aperture in the wall of an enclosure maintained at thermal equilibrium was measured, but the nature of the distribution could not be explained by any existing theory. At last Planck was able to provide one. Einstein further interpreted Planck's hypothesis. He suggested that the radiant energy emerges in packets and 'quanta'. Still it was not satisfying. Bose worked on it on his own and succeeded not only in providing a self-contained derivation of Planck's formula, but also introducing new concepts in physics, later known as 'Bose Statistics'. Einstein now understood its significance and applied it to the case of ideal gas and found a new relation, known as 'Bose-Einstein Statistics'.

Bose was soon ready with another paper named 'Thermal Equilibrium in Radiation Field in Presence of Matter'. He sent this paper also to Einstein. It was translated by Einstein and published in *Zeitschrift fuer Physik* in 1924. But in this case Einstein remarked that he did not agree with Bose's hypothesis and cited reason therefor. Einstein's comments on his paper helped him in securing a passport for his Europe tour for two years. Einstein's hand-written letter admiring Bose's paper to be a major contibution in the field of science was accepted as a bonafide recommendation, and the German Consulate in Calcutta did not hesitate to issue a visa to Bose. He sailed from Bombay and arrived in Paris in October, 1924.

In Paris Bose met Madame Curie who had already been aware of Bose's work. Madame Curie agreed to have Bose working with her in her laboratory. But she suggested that Bose must learn French first and then come to her. Bose learnt French and after about five months he worked for some time in the Radium Institute in Paris. There his mind was drawn towards X-ray crystal structure analysis. He met the famous de Broglic brothers who were engaged in original research in X-ray crystallography. Thus he came in close touch with many prominent European scientists.

In 1925 Bose met Einstein in Berlin. There he spent one year, attending seminars and conferences of science, and coming in contact with a good number of prominent scientists like Fritz Haber, Otto Hahn, Lise Meitner, Walter Bothe, Hans Geiger, Peter Debye, Von Laue, Wolfgang Pauli, Werner Heisenberg etc., some of whom were the recipients of the Nobel Prize.

On his return to India in 1926, Bose developed a well-equipped X-ray crystallographic laboratory at the Dacca University. Since then the Physics Department of the University had developed greater facilities for research work in X-ray spectroscopy, X-ray diffraction, magnetic properties of matter, optical spectroscopy including Raman Spectra, Wireless etc.

Bose used to invite eminent scientists like C. V. Raman, Meghnad Saha, D. M. Bose, Sisir Kumar Mitra and B. B. Roy as external examiners for the M. Sc. practical and viva voce examinations at the Dacca University. In 1929 Bose delivered the Presidential Address of the Physics and Mathematics Section of the Indian Science Congress, when he spoke on 'Tendencies in Modern Theoretical Physics'.

In 1944 Bose became the General President of the Indian Science Congress. He delivered his Presidential Address on 'The Classical Determination and the Quantum Theory'. As Dean of the Science Faculty and the Provost of the Dacca Hall, he weilded considerable power in the University circle till his stay there upto 1945. Thereafter he came to Calcutta. The Faculty and the students of the University College of Science and Technology gave Bose a very hearty welcome when he joined as 'Khaira Professor' of Physics of the Calcutta University.

Bose became the President of the Indian Physical Society from 1945 to 1948. He also became the President of the National Institute of Science from 1948 to 1950. He visited Europe every year from 1951 to attend various scientific conferences.

In 1952 Bose was nominated a Member of the Rajya Sabha, and he continued as such till 1958. In 1953 he attended the 'World Congress for General Disarmament and Peace' at Budapest. He also visited U. S. S. R., Denmark, Czechoslovakia, Geneva, Paris, Copenhagen, Zurich and Prague. He met Professor Pauli in Zurich, and Niels Bohr in Copenhagen. Bose was basically a theoretical Physicist. But in 1954 he presented at the Crystallographic Conference in Paris, a paper describing a new and significant thermo-luminescence analyser developed by his pupils under his guidance. In 1954 the Government of India honoured him with the title of *Padma Bibhusan*. In 1956 Bose retired from the post of the 'Khaira Professor', and became the Vice-Chancellor of Viswabharati University. In the same year he attended the Annual Meeting of the 'British Association for the Cultivation of Science' in England.

In 1957 other honours and academic distinctions came his way. Three Universities—Calcutta, Jadavpur and Allahabad—gave him honorary Doctorate degrees. In the same year Bose was appointed an Emeritus Professor in the Calcutta University. He was also appointed the National Professor by the Government of India, and the Emeritus Professor of Indian Association for the Cultivation of Science at Jadavpur.

In 1958 he attended the Royal Society meeting in London where he was nominated as a Fellow. In 1962 he went to Sweden and from there to Moscow to attend Peace Conference. In the same year he was invited to attend a seminar on science and philosophy in Japan, which was organized in memory of the atomic explosion over Hiroshima and Nagasaki.

In 1964 on the occasion of his 70th birthday, the Science Congress held at Calcutta a seminar on 'Bose Statistics and Unified Field Theory' in his honour, and the Delhi University observed his birthday with a seminar on 'Forty Years of Bose Statistics' and presented him a collection of articles on 'Bosons' edited by R. C. Mazumdar.

Bose continued as the National Professor for three consecutive terms, each of five years' duration. In 1974, as he completed eighty, nation-wide celebrations were organized in his honour. This year coincided with the golden jubilee of 'Bose Statistics', and hence an international seminar was held at Calcutta, which was attended by scientific celebrities from all over the world.

Professor Satyendra Nath Bose died on 14 February, 1974, after an attack of bronchial pneumonia.

Bose was well-known for his philosophical temperament, broad interest in national problems and education, and particularly for his championing the cause of popularizing and teaching science in mother tongue.

Bose had always been deeply interested in the fundamental problems of mathematical physics. His name is inseparably associated with Albert Einstein. The famous 'Bose–Einstein Statistics' is a distinct improvement over the earlier statistics in the names of Maxwell and Boltzman, which as Bose pinted out is applicable to the gaseous molecules but not to the individual photons. Bose's contribution to unified field theory is also well-known. The modern scientists have expressed their appreciation and indebtedness to Bose by classifying subatomic particles into two categories: 'fermions' named after Fermi, and 'bosons' after Satyen Bose.

Professor P. K. Kabir writes : Bose's paper not only had an immediate and far-reaching impact on several basic problems in physics but it also provides the fundamental explanation of phenomena whose elucidation and elaboration have been the subject of at least three Nobel Prizes. It is a great pity that this token of honour was not accorded to S. N. Bose whose work is undoubtedly the most important contribution to science made by any Indian so far".

Professor M. G. K. Menon comments : "I have never understood personally why Satyen Bose was never awarded a Nobel Prize nor have the many very distinguished scientists with whom I have conversed on this subject. The question that we should ask, in terms of the decades and centuries ahead, is not whether a scientist has received a Noble Prize, but whether his name will survive in the pages of science that all will read, discuss and constantly use. In the latter category will come Satyen Bose. 'Bose–Einstein Statistics' and the use of the word 'Bosons' will live on a permanent basis in the history of science."

A true scholar will always be on a level high above the merely successful scientist. Honour came to him at the end of his life. He was made an F. R. S. only in 1958. Various national awards and honours also came to him during the post–independence period. In his reply to a friend, once he said, 'I have received my due'. Because he knew that he had received the affection and respect of the vast majority, both at home and abroad over many years, which he considered more important and precious than any award.

SHANTI SWARUP BHATNAGAR

(1894–1955)

Shanti Swarup Bhatnagar was born on 21 February, 1894 at Bhera in Punjab. He had his education in Lahore and London. He took his M.Sc. in Chemistry in 1919 and D.Sc. from the London University in 1921. He first joined the Banares Hindu University in 1921 as Professor of Chemistry. Later, he served the Punjab University for 16 years from 1924–40. He made a magnificent donation of Rs. 1,50,000 to the Punjab University for promoting research. The said money he had earned for his work in an industrial firm in the U. K.

S. S. Bhatnagar

In 1940 Bhatnagar became the Director of the Board of Scientific and Industrial Research which later became the CSIR. He was the first Secretary of the Atomic Energy Commission and the Chairman of the University Grants Commission.

Bhatnagar was also a poet, playwright and an actor. But he contributed the most to colloid chemistry and magneto chemistry. He developed in the field of applied industrial chemistry, products such as anti-gas cloth and varnish, anti-foam solution, vegetable oil blends as lubricants and fuel, unburstable containers, glass substitutes, dehydrated castor oil and plastics from Indian wastes. He was a rare type of organizer and was instrumental in setting up the first 12 national laboratories in India.

When Bhatnagar donated the huge sum to the Punjab University for development of research work, Meghnad Saha, the famous scientist among others, wrote to him : "India does not lack in men earning millions, but, if a few of those millionaires were guided by the fine example set by a comparative poor teacher like yourself, I think her scientific and moral progress would have been rapid. Nobody but a true researcher can feel how much of our energies in this country are being wasted for lack of funds".

Bhatnagar turned out to be one of the great builders of scientific institutions in India. He carried out his research work to make wax odourless, refine kerosene to increase flame height and utilize petroleum waste in the oil industry. The famous Bhatnagar-Mathur interference balance, which he designed and fabricated in collaboration with R. N. Mathur, a Physicist, is of immense use in such studies. A British firm manufactured this balance for worldwide market.

Bhatnagar was elected Fellow of the Royal

Society of London in 1943 for his valuable scientific contributions. After independence of India, Bhatnagar being encouraged by Jawaharlal Nehru, took initiative for installing in India oil refineries, plants to produce newer metals, such as titanium and zirconium, and planning surveys for atomic minerals and petroleum deposits. In his honour the Council of Scientific and Industrial Research awards every year the "Shanti Swarup Bhatnagar Prize for Science and Technology", a sum of Rs. 20,000, to scientists for their outstanding contributions to science, engineering, and technology.

Bhatnagar died on 1 January, 1955.

KARIAMANIKKAM SRINIVASA KRISHNAN

(1898–1961)

K. S. Krishnan was born on 4 December, 1898 in the village of Watrap in Tirunelveli District of Tamil Nadu. He had his education at Srivillipputtur, Madurai and Madras. He took both his M.A and D.Sc. Degrees from the Madras University. After serving his own college, the Madras Christian College, as a Demonstrator in Chemistry, he joined as a Research Associate at the Indian Association for the Cultivation of Science, Calcutta in 1920. He collaborated with Raman in making a detailed examination of the changes in the frequency and polarization of light.

K. S Krishnan

Krishnan, after working with Raman for some time, pursued independent investigations. His research interest was broad and covered diverse topics, such as magnetic properties of crystals, energy distribution of electrons in graphite crystals, metal physics, light scattering, thermionics etc. He was supremely gifted as an experimentalist.

From 1929–33 Krishnan was at the Dacca University as a Reader in Physics. Rejoining the

Calcutta University in 1933, he did a great deal of research in crystallography. Krishnan became the Professor of Physics in the University of Allahabad in 1943. There he undertook studies on electrical conductivities of metals and alloys. After the independence of India, Krishnan who had already earned his international reputation as a prominent scientist, was offered the Directorship of the National Physical Laboratory, where he had mostly concentrated on the problems of thermionics, the study of electrons emitted by a hot body, and their behaviour and control. He presided over the Indian Science Congress in 1949. He was a Member of the Atomic Energy Commission from 1949–61. He studied how heat is distributed in solids of various shapes, namely rods and coils, when heated in a vaccum. This has wide industrial application.

Krishnan received several honours and was elected Fellow of the Royal Society of London in 1940. He passed away on 13 June, 1961.

Of Krishnan, Pandit Jawaharlal Nehru said, "He is a good scientist, but something much more. He is a perfect citizen, a whole man with an integrated personality."

DAULAT SINGH KOTHARI

(1906–)

Daulat Singh Kothari was born on 6 June, 1906. He took his M. Sc. from Allahabad and Ph. D. from Cambridge. He was Professor of Physics at the Delhi University from 1934–48. He was appointed Scientific Adviser to the Ministry of Defence, Government of India for 13 years from 1948. He became Chairman of the University Grants Commissions in 1961 and headed the Education Commission in 1965.

D. S. Kothari

Kothari, a favourite student of Prof. Meghnad Saha, pursued his scientific research on astrophysics. He laid the foundation of the 'theory of pressure ionisation', according to which very high pressure unaided by thermal factors could ionise materials. He deduced that such degenerate matter existing under high pressure and low temperature condition (as in white dwarf stars) cannot force an object having *volume* greater than a critical limit (size of the Jupiter planet).

In the capacity of the Scientific adviser to the Ministry of Defence, Kothari initiated useful research projects behaviour of metals under explosive pressure and also on battistics, electronics etc.

Kothari was the first to visualize that pressure alone, unaided by heat, could suffice to smash the atoms. Kothari's contribution to the 'defence science' is substantial, covering a wide range. It was he who pioneered research in study of competing weapon systems ; improvement of weaponry ; and development and design of new as well as older existing weapons with a view to their indigenous manufacture.

Kothari, along with Dr. Auluck, found an application for Ramanujan's theory of partition of numbers, which would otherwise have been consigned to realm of 'pure theory'.

Kothari takes his place along with M. N. Saha and C. V. Raman for his research in astro-physics. He was responsible for setting up of the Defence Science and Research Organization in India.

HOMI JEHANGIR BHABHA

(1909–1966)

Homi Jehangir Bhabha was born on 30 October, 1909. He had his early education in Bombay. In 1927 he joined the Cains College, Cambridge, for engineering studies. His interests lay in mathematics, and on fulfilling the promise of securing a first class in mechanical sciences, his kind father allowed him to pursue his mathematical interests. He joined the Cavendish Laboratory in 1931 and, with the help of a travelling fellowship, worked with Pauli in Zurich, Fermi in Rome and Kramers in Utrecht. He took his Ph.D. at Cambridge in 1935. His first scientific paper in 1933 considered the part played by electron showers in the absorption of gamma radiation and won for him the Issac Newton Studentship in 1934.

H. J. Bhabha

During a period of 22 years (1932–54), he produced 50 scientific papers on high energy physics. He was the first person to calculate the cross-section for election–positron scattering which is known as 'Bhabha-scattering'. He discovered new sub-atomic particles—his meson-theory.

Bhabha's chief scientific contribution has been the 'cascade' theory of cosmic-ray showers, relating to the soft component of secondary cosmic rays. He worked out the detailed mathematical aspects of his theory.

Bhabha has undoubtedly been one of the chief architects of research in fundamental physics in India.

The recognition of Bhabha's leadership in the field of nuclear research was evident from the fact that he was elected to preside over the international conference on the peaceful use of atomic energy held at Geneva in 1955.

In the first phase of his research work, he displayed knowledge of and skill in methods of modern algebra to a degree quite unusual among theoretical physicists of the time. He also proved in his work that he could see further ahead than most of his contemporaries : as resonances in high energy collisions, particles of higher spin are today part of the observed external world.

The origin of India's nuclear power programme can be found in the speeches and writings of Homi Bhabha from around 1955 to the time of his untimely death in 1966. His ideas got crystallized towards the late fifties and early sixties. He propounded the policy of the three-stage fuel cycle strategy. The three stages are natural uranium, heavy water reactors in the first stage followed by fast reactors using plutonium from the first stage reactors and depleted uranium or thorium in the blanket, and the third stage reactors employing the uranium 233—thorium cycle.

When Bhabha formulated this strategy, many aspects of the technology of fast breeder reactors, reprocessing and recycling of plutonium were only vaguely understood. This was a clear case crystal gazing.

The role of fast reactors, fuel reprocessing and recycling plutonium were recognized in due time, and these programmes were pursued vigorously in the country.

Bhabha also injected the idea of developing self-reliant capacity into the programme. Manufacture of equipment for nuclear power plant within the country was taken up right from the early days of the programme.

The calculations made by Bhabha, revealed nuclear power to be economic in load centre locations (away from coal mines). Tarapur station has been supplying the lowest cost non-hydro electric power, creating a sizable financial surplus.

Bhabha became a Reader at the Institute of Science, Bangalore in 1940, and a Professor there in 1942. His work at the Institute was more mathematical than what he had done and was concerned with the movement of particles in a 'general field'. Mainly at his instance, the Tata Institute of Fundamental Research was set up in Bombay in 1945, and he became its first Director. His advocacy of the nuclear power development in India led to the enactment of law on atomic energy in India : the Indian Atomic Energy Act of 1948. Bhabha was entrusted with the responsibilities of implementing the provisions of the Act in August, 1948.

Through Bhabha's persuasion, the decision was taken by the Government of India to set up India's first atomic energy establishment (a complex of plants) at Trombay in January, 1954. In 1954 Bhabha became the Secretary of the Department of Atomic Energy set up under the terms of the 1948 Act. The Lok Sabha passed a Resolution in 1958 of setting up the Atomic Energy Commission, and Bhabha became the ex-officio Chairman of the Commission.

The Atomic Energy Establishment was renamed 'Bhabha Atomic Research Centre' on 12 January, 1967, a year after the untimely death of Bhabha in an aircrash on Mount Blanc On 24 January, 1966.

Bhabha was elected Fellow of the Royal Society for his contributions relating to cosmic rays, elementary particles and quantum mechanics. Under his expert guidance three atomic reactors, Apsara, Cirus, and Zerlina were built in India. Survey for uranium ore continued, and plants to purify the required materials were also built. He was mainly responsible for India's atomic energy development programme and the Space Research Programme.

There were a few honours which Bhabha had not, however, received in his life-time as a scientist of outstanding calibre.

SUBRAHMANYAM CHANDRASEKHAR

(1910-)

Subramanyam Chandrasekhar was born on 19 October, 1910 in Madras. He took his M. A. from Madras University in 1930. He was a Government of India scholar at the Cambridge University during 1930–34, when he took his Ph.D. Later, he became a Fellow of Trinity College. In 1938 he joined the Chicago University as Assistant Professor. Subsequently, he became the Morton D. Hull Distinguished Service Professor of Theoretical Astrophysics, Chicago in 1952. He received the Noble Prize for Physics in 1983.

S. Chandrasekhar

As a nephew of C. V. Raman, he had received an early inspiration for a scientific career from Raman. He carried on his research work on astrophysics for some time, and then went to the West, where he was at Cambridge, U.K., and at Chicago, USA. He took American citizenship in 1953, and in due time received the highest national award on scientific achievement from the U.S. President.

Chandrasekhar's vast output of scientific work relates to : course of stellar and galactic flames, properties of 'Plasma' (ionised gas) under high temperature, pressure and magnetic field, effects of gravitation, electromagnetism and turbulence on stellar and galactic matters etc.

'Chandrasekhar Limit' and 'Black Holes' are terms that have gone into the vocabulary of astrophysics. In 1935 he had come close to speculating on the formation of 'black holes', superheavy heavenly objects, a spoonful of which weighs several thousands of tons. His 'limit' imposes a restriction on the size of a highly dense variety of star known as the White Dwarf. If this type of star has mass in excess of the limit, it explodes to become a very bright star, called *Supernova,* until all the excess matter is shed into space.

Chandrasekhar has also made significant contributions to understanding the atmosphere of stars and the way matter and motion are distributed among the stars in a galaxy. His work on rotating fluid masses and the blueness of the sky is also well-known.

Chandrasekhar is a Physicist, an Astro-physicist and an Applied Mathematician, living today being engaged in his study of the effect of gravity and electromagnetic fields on rotating 'black holes'.

VIKRAM A. SARABHAI
(1919-1971)

Vikram A. Sarabhai

Vikram A. Sarabhai was born on 12 August, 1919. He took his B. A. degree with physics and mathematics from Cambridge University in 1940. After doing post-graduate research under Dr. C. V. Raman (cosmic rays), Sarabhai took his Ph. D. from Cambridge in 1947. His thesis was on 'Cosmic Ray Investigations in Tropical Latitudes'. He was the first Director of the Physical Research Laboratory of Ahmedabad. He set up the Ahmedabad Textile Industry's Research Association, and the Indian Institute of Management.

Sarabhai was the second Chairman of India's Atomic Energy Commission and the Indian Space Research Organization. His important planning included India's first satellite, *Aryabhata* which was launched in 1975. The Satellite Instructional Television Experiment (SITE) in 1975-76 sought to bring education to five million people in 2,400 Indian villages. He was also responsible for the Equatorial Rocket Building Station at Thumbe.

Sarabhai's study of cosmic rays revealed that cosmic rays are a stream of energy particles reaching the earth from outer space, being influenced on their way by the sun, the atmosphere and magnetism. Sarabhai understood that the event occurring in space among the planets, invariably affect the rays. The study of cosmic rays helps in observing terrestrial magnetism and the atmosphere, the nature of the sun and outer space.

Sarabhai received many honours and awards for his contribution to science and industry. The International Astronomical Union named after him a crater on the moon in the Sea of Serenity.

Sarabhai passed away in 1971.

HARGOVIND KHORANA

(1922–)

Hargovind Khorana was born at Raipur in 1922. He took his B. Sc. and M. Sc. in Chemistry at the University of Punjab in Lahore (now in Pakistan). In 1945 he went to the University of Liverpool in Britain on a Government of India scholarship and obtained his Ph.D. in Organic Chemistry there.

H. G. Khorana

In 1959 Khorana produced a chemical called 'coenzyme A' which is essential for certain processes in the human body, while he was at the University of British Columbia in Canada. This made him soon known in the world of science. Thereafter he moved to U.S.A. and joined the Institute of Enzyme Research of the University of Wisconsin there. In 1970 he joined the Massachussetts Institute of Technology as the Alfred Sloan Professor of Biology and Chemistry. His chief work has been in biochemistry and molecular biology.

At the age of 46, Khorana shared the 1968 Nobel Prize for medicine with Marshall W. Nirenberg and Robert W. Holley. All the three scientists had independently made their contributions to the understanding of the genetic code. Khorana was responsible for producing a part of the gene of yeast cell in his laboratory,

Escherichia Coli is a bacteria that lives in the intestines of human beings and animals. Khorana and his team of scientists built up piece by piece, the 207 gene of *Escherichia Coli* in the laboratory. Signals of 'stop' and 'start' were also added to the gene. In 1976 the man-made gene was inserted into *Escherichia Coli* in August, 1976, and it began to work like its natural gene. This wonderful success was hailed all over the world as a major triumph of modern biology.

Khorana and his team of twenty-four scientists took more than nine years to produce one gene of *Escherichia Coli* bacterium. It is, no doubt, a hard task which requires patience and devotion to work. Khorana continued his study to know how a gene functions in a cell, and why it works when wanted and what makes it stop. His studies may perhaps some day find out what causes genetic defects, and how and why cancer is caused.

Like S. Chandrasekhar, Har Govind Khorana also settled in USA, and was lost to Indian science.

RAJA RAMANNA

(1925—)

Raja Ramanna was born on 28 January, 1925 in Mysore. He had his early education in Mysore, and took his B. Sc. (Hons. in Physics) from the Madras University (the Madras Christian College). He took his Ph. D. in Nuclear Physics from the King's College of Science under the London University in 1948. He had the opportunity of working under Prof. Allan Mann on Manhattan Project which developed the world's first nuclear bomb.

Raja Ramanna

In 1949, Ramanna joined the Tata Institute of Fundamental Research as a Professor and subsequently he became the first Head of the Nuclear Physics Division of the Bhabha Atomic Research Centre. He joined the Atomic Energy Establishment at Trombay in 1953. His work was two-fold : in research at pure science level in exploring the frontiers of nuclear physics through a resourceful deviation from conventional mathematical techniques ; and in the creation of a base of multi-disciplinary research and development capability to bring the fruits of knowledge within the reach of all.

Ramanna became the Director of BARC in 1972. He was the Scientific Adviser to the Defence Research and Development Organisation, and the Secretary in the Ministry of Defence in 1978. He was the Secretary in the Department of Atomic Energy in 1981, and the Chairman of Atomic Energy Commission from 1983 to 1987.

Ramanna's main work has been in the field of fission physics and neutron thermalization. He has conducted a detailed experimental study of the fission process and has developed a scholastic theory to explain this process. He has to his credit the design, installation and commissioning of the atomic reactors : *Apsara, Cirus* and *Purnima*. He led the team that was responsible for the explosion of the underground nuclear device at Pokhran, a desert in Rajasthan on 8 May, 1974.

Ramanna played a key-role in the design of the various reactors at Trombay. A Fellow of the Indian Academy of Sciences, he won the 'Shanti Swarup Bhatnagar Memorial Award' for Physical Sciences in 1963. He was awarded the *Padmashri* in 1968.

Ramanna is an accomplished pianist. He is keenly interested in ancient Indian philosophy. He is now the Chairman of Indian Institute of Science, Mysore.

MANKOMBU SAMBASIVAN SWAMINATHAN

(1925—)

M. S. Swaminathan was born on 7 August, 1925 at Kumbakonam in Tamil Nadu. He graduated from the Agricultural College, Coimbatore (now Tamil Nadu University) in 1947. He was UNESCO fellow at the Department of Genetics of the Netherlands Agricultural University, Wageningen during 1949. He took his Ph. D. from Cambridge in 1952.

M. S. Swaminathan

After working as a Research Associate in genetics at the University of Wisconsin, Swaminathan returned to India in January, 1954, when he was initially employed at the Central Rice Research Institute, Cuttack. He was the Assistant Cytogeneticist at the Indian Agricultural Research Institute (IARI) from October 1954 to 1961. From 1961 to 1966 he was the Head of the Division of Genetics of IARI. He became the Director of IARI in 1966, and the Director-General of IARI in January 1972. In 1973 he was elected Fellow of the Royal Society. He is a recipient of many honours and awards including the 'S. S. Bhatnagar Award', the 'Birbal Sahni Medal', and 'Mendel

Memorial Award'. In 1971 he was awarded the 'Raman Magsaysay Award'. In its citation he has been described as "scientist, educator of even students and farmars, and administrator towards generating a new confidence in India's agricultural capabilities." He presided over the Indian Science Congress in 1976.

Swaminathan retired from Government service in 1980, after serving as the Secretary of the Ministry of Agriculture from March, 1979. After his retirement, he was Member of the Planning Commission. He has been the Director-General of the International Rice Research Institute, Phillipines since 1981.

Swaminathan's main field of research has been plant genetics. As the agriculture scientist-administrator he gave a push to India's Green Revolution. His research wark included study of various crops and the basic or applied geneties at the Agricultural Research Institute. He introduced modern methods and techniques to develop agricultural products, that yeilded substantial growth in wheat and rice and achieved remarkable development in potato, jute and some other species.

MAMBILLIKALATHIL GOVIND KUMAR MENON

(1928—)

M. G. Menon was born on 28 August, 1928. His father was a District and Session Judge at Mangalore in Karnataka. He took his B. Sc. from Agra University, and M. Sc. from Bombay University. He obtained his Ph. D. from Bristol University in U. K. He worked with Prof. C. F. Powell, the Nobel Laureate at the University of Bristol. From 1953 to 1955 he held the senior Award of the Royal Commission for the Exhibition of 1951.

M. G. K. Menon

Menon joined the Tata Institute of Fundamental Research in 1955 and became its Director in 1966. He developed the technology of fabricating and flying very large balloons under tropical conditions through the very low temperatures of the equatorial tropopause. This is now a facility that enables cosmic ray work at high altitudes close to the geomagnetic equator to be carried out of India. The significant work of the TIFR cosmic ray group on the high energy X-ray sources are illustrative of the importance of this facility.

During his research under C. F. Powell he discovered a few 'elementary particles' which included muons of varying energies, K-particles and a specific category of pions.

Menon won the 'Shanti Swarup Bhatnagar Memorial Award' for Physical science in 1960. He was awarded the ***Padmashri*** in 1961, and ***Padma Bhushan*** in 1968.

In 1974 Menon joined the Government of India as the Scientific Adviser to the Ministry of Defence. After holding the posts of Director-General, Defence Research and Development Organisation, the Secretary in the Ministry of Defence for R & D, the Secretary of the Department of Science and Technology, the Director-General of the Council of Scientific and Industrial Research, he is now a Member of the Planning Commission and Scientific Adviser to the Prime Minister of India since 1986. Menon was also the Chairman of the Electronics Commission, and elected Fellow of the Royal Society.

JAYANT VISHNU NARLIKAR

(1938—)

Jayant Vishnu Narlikar was born at Kolahpur, Maharashtra on 19 July, 1938. He took his B.Sc. from the Benares Hindu University in 1957, and his M. Sc. (1962), and Ph. D. (1963) and finally D. Sc. (1976) from the University of Cambridge, U. K.

J. V. Narlikar

Narlikar's educational career was marked by excellence and in recognition thereof he received several scholarships and prizes, including a J. N. Tata Scholarship (1957–1963) ; the Tyson Medal and Prize (1960) ; the W. A. Meek Scholarship, Cambridge University (1961–1962) ; the Berry–Ramsay Prize Fellowship, King's College, Cambridge (1963–1969) ; Smith's Prize, Cambridge University (1962) ; and Adams Prize, Cambridge University (1967).

Narlikar was a Senior Research Fellow at King's College (1969-1972) ; a Staff Member, Institute of Theoretical Astronomy, University of Cambridge (1967–1972) and a Jawaharlal Nehru Fellow (1973–1975). He has been Professor of Astrophysics at the Tata Institute of Fundamental Research, Bombay since 1972.

Narlikar worked on the 'steady state' theory of the University. It implies that the universe remains static, — the same as in the past, present or future, and that matter in the form of stars, galaxies and other bodies is distributed in a balanced way all over the universe. The gap which is sometimes created due to the motion of a galaxy or any other body, is filled up with new matter automatically. Narlikar could not accept this theory totally, as a definite case has not been established in support of this theory.

He has also worked on 'tachyons' that are faster than light particles, and 'black holes' that are highly concentrated celestial bodies of high gravity. For example, one spoonful of a 'black hole' weighs as much as a few tons, and hence it does not allow even light to escape from its surface. Narlikar says that 'black hole' can absorb tachyons and reduce its own surface area.

Narlikar's greatest contribution to modern science is the theory of gravitation which he propounded in collaboration with the famous British scientist, Prof. Fred Hoyle, and also the polarization of the action at a distance technique in physics and cosmology.

As a Jawaharlal Nehru Fellow, Narlikar worked on Theoretical Physics and Astronomy. The Fellowship enabled him to write a technical book in collaboration with Prof. Fred Hoyle : 'Action at a Distance in Physics and Cosmology' (W. H.

Freeman, San Francisco, 1974) and a non-technical book on 'The Structure of the Universe' written by him alone (Oxford University Press, 1977). He is also the author of a number of scientific papers on Astronomy, Relativity, Gravitation and other aspects of theoretical physics.

M. R. SRINIVASAN

(1930—)

M. R. Srinivasan was born on 5 January, 1930 in Bangalore, Karnataka State. His early education was at Bangalore. He topped his class in all the four years of the engineering course and secured several distinctions and prizes for being the best student. He did post-graduate studies at McGill University, Montreal, Canada. He was awarded a doctorate in 1954 by the McGill University for his thesis on 'Combustion Problems in Gas Turbines'.

Dr. Srinivasan joined the Department of Atomic Energy in September, 1955 and actively participated in the construction of India's first research reactor *Apsara*. In 1959 he was made responsible for the execution of India's first atomic power station at Tarapur. This was the first atomic power station in Asia outside the Soviet Union, when commissioned in 1969. Dr. Srinivasan directed the work on the Madras Atomic Power Station from its inception till its successful commissioning. This is an indigeneously built atomic power station.

In 1974 Dr. Srinivasan became the Director of the Power Project Engineering Division (PPED) of the Department of Atomic Energy, which was later reconstituted and made the Nuclear Power Board (NPB) with increased responsibilities. He became the Chairman of the Nuclear Power Board on 29 May, 1984, and a Member of thc Atomic Energy Commission in 1985.

Dr. Srinivasan is the recipient of the Sanjay Gandhi Award for Science and Technology in the field of energy for the year 1983, and also of *Padmashri* in 1984. He is the Chairman of the Atomic Energy Commission (AEC) and Secretary, Department of Atomic Energy since 28 February, 1987.

About the development of atomic energy and its use in India, Dr. Srinivasan says: "India is one amongst a small group of countries which have capability to design, build and operate nuclear power stations, to mine, process and fabricate uranium fuel elements and to reprocess the spent fuel, separate plutonium for re-use and vitrify waste for long term storage. In technical parlance India has mastered all facets of the nuclear fuel cycle. India is also one of the few countries which have entered the fast reactor field. In the field of research and development in nuclear science and technology, India possesses comprehensive capabilities in all the disciplines such as physics, chemistry, metallurgy, biology etc.

India's main achievement has been the creation of self-reliant capability in all facets of nuclear technology. Thus when India commissioned the first unit of the Madras Atomic Power Station in 1983, it joined a select group of countries which had the ability to design and build nuclear power stations on their own. These countries are U.S.A., U.S.S.R., France, U.K., Canada, Federal Republic of Germany, Sweden and Japan. Similarly, when the Fast Breeder Test Reactor at Kalpakkam was commissioned in 1985, India became a member of a small club consisting U.S.A., U.S.S,R., U.K., France, Federal Republic of Germany and Japan. These are noteworthy achievements.

On the other hand, the amount of electricity generated from nuclear power stations in India at present is only around 3%. This may be compared with 16% for the world as a whole. In fact, in France nuclear electricity accounts for over 70% of the electricity produced in that country. At present 60-65% of the electrieity produced in India is from coal fired stations and 30-35% from hydro-electric power stations. In the long run there is a need to use nuclear power in a much greater measure for electricity production.

The goal India has set for nuclear power by the end of the century is 10,000 MWe installed capacity. At that time the country will be having a total generation capacity of 100,000 to 120,000 MW.

From the point of view of power needs of the country, a much larger nuclear power capacity would be welcome. In order to achieve a rapid increase in nuclear power capacity, it is necessary to build a series of 500 MWe reactors. By using a standardized design and locating a number of units at a given site, it may be possible to cut down the generation period of these projects."

PADMANABHA KRISHNAGOPALA IYENGER

(1931–)

Padmanabha Krishnagopala Iyenger was born on 29 June, 1931. He took his M. Sc. from the University of Travancore in 1952 and Ph. D. from the University of Bombay in 1963.

Iyenger started his career as a physicist working with low energy accelerators. His major area of research is 'Neutron diffraction and Inelastic Scattering from Solids and Liquids'. His wider interest in solid state of physics is revealed by his contribution in the area of magnetism by the Mossbaur Techniques and Neutron Diffraction. He has contributed significantly to the physics of fast reactors. Dr. Iyenger has trained hundreds of scientists at the BASC Training School. He has written more than 100 research papers.

Dr. Iyenger is at present the Director of the Bhabha Atomic Rerearch Centre (BARC) and Member of the Atomic Energy Commission.

E. C. G. SUDARSHAN

(1931—)

E. C. G. Sudarshan was born on 16 September, 1931 in Kottayam, Kerala State. He had his education in Kottayam, Madras and Rochester (New York). He is at present the Director of the Institute of Mathematical Science, Madras.

Sudarshan took his M.A. from Madras University in 1952, and Ph. D. from the University of Rochester (1955-58). He was Research Assistant at the Tata Institute of Fundamental Research during 1951-55. He is associated with the University of Rochester, the Syracuse University, the University of Texas, and the Indian Institute of Science, Bangalore.

At Rochester, he attended a lecture by Abdus Salam and got his first research problem on the magnetic moments and mass differences of hadrons. His scientific interests have spanned a wide spectrum, with primary concentration on particle physics and its theoretical scaffolding, quantum field theory. He has identified 'tachyons' (hypothetical particles moving faster than light). Dr. Sudarshan has published more than 200 technical papers. His publications include 'Elementary Particle Physics' (with R. E. Marshak), 'Fundamentals of Quantum Optics', and 'Classical Dynamics'.

In addition to many degrees of Doctor of Science from universities of India and abroad, Dr. Sudarshan has received a number of other honours and awards, including that of ***Padma Bhusan*** from the President of India in 1976. Probably the most outstanding award received by him so far, was the 185 ***Physics Prize*** (with a cash award of 10,000 U.S. Dollars) by the Third World Academy of Sciences, with its headquarters at the International Centre for Theoretical Physics in Trieste, Italy. It was given in recognition of Professor Sudarshan's fundamental contribution to the understanding of the Weak Nuclear force, and particularly for his part in the formulation of the 'University V–A Theory' of Marshak and Sudarshan.

Dr. Sudarshan is an unusual type of person who can be described as a physicist by vocation and a philosopher by avocation, a scientist by training, but a Sanskritist by cultural background, who can manage the 'two cultures' in one creative world of comprehension.

Sudarshan believes : "Physics is a spiritual discipline, since it aims to comprehend all that is dynamic in a single magnificient vision."

U. R. RAO

(1932—)

U. R. Rao was born on 10 March, 1932. He obtained his Ph. D. in 1960 from Physical Research Laboratory (PRL), Ahmedabad in the field of cosmic rays. He joined the Massachusetts Institute of Technology (MIT) as a post-graduate doctoral Research Fellow in 1961, where he worked on cosmic ray modulation and in the investigation of solar wind properties. In 1963, he joined the then Southwest Centre for Advanced Studies, Dallas, as an Assistant Professor, where he continued his cosmic ray investigations. He was the principal investigator for cosmic ray experiments which were successfully flown on pioneers 6, 7 and 8 deep space probes and Explorer 34 and 41 satellites. The results of his experiments have proved a completely new insight into the interplanatory physics.

After rejoining PRL in 1966, Rao initiated new programme of research in the field of X-ray and Gamma Ray astronomy using balloon-borne, rocket-borne and satellite payloads. The X-ray payload fabricated by his group was also successfully flown on the first Indian satellite 'Aryabhata'.

Dr. U. R. Rao is the Chairman, Space Commission and Secretary, Department of Space, Bangalore.

OTHER MODERN INDIAN SCIENTISTS

India is proud of her eminent scientists, some of whom have been introduced here. There are many more renowned Indian scientists whose particulars could not be furnished in this small volume. A few more names are, however, given below :

Dr. Karm Narayan Behl (1891-1954) is known for his work in Zoology. Biman Behari Dey (1889-1959) is known for Organic Chemistry ; Jnan Chandra Ghosh (1893-1959) : Chemistry ; and Prafulla Chandra Mitter : Chemistry ; Prakriti Kumar Ghosh (1899-1960) : Geology ; Hemendra Kumar Sen (1888-1945) : Geology ; Sisir Kumar Mitra (1890-1963) : Ionosphere ; Dr. Satish Dhawan (b. 1920) : Space Technology, and his notable contribution has been the design and construction of supersonic and transonic wind tunnels and the setting up of the High Speed Aero Dynamics Laboratory ; J. B. S. Haldane (1892-1963) : Biochemistry ; B. P. Pal (b. 1906) : Botany ; A. S. Paintal : Medical Science ; D. N. Wadia (b. 1883) : Geology ; R. C. Bose (b. 1901) : Mathematics ; Nikhil Ranjan Sen (1894-1963) : Applied Mathematics ; Biresh Chandra Guha (1904-1962) : Bio-chemistry ; Tejendranath Ghosh (1904-1962) : Chemistry ; Ramesh Chandra Ray (1890-1959) : Chemistry ; Dhirendranath

Majumdar (1903–1960) : Anthropology ; Austin Manindra Nath Ghosh (1902–1961) : Geology ; Himadri Kumar Mukherjee (1898–1955) : Zoology ; Panchanan Maheshwari (1904-1966) : Embryology ; Sunderlal Hora (1886–1955) : Zoology ; Dr. Atma Ram (1908–1986) : Chemistry, Glass and Ceramics ; Sir T. S. Venkataraman : Sugarcane ; Dr. Ganesh Prasad : Mathematics ; Dr. C. R. Rao (b. 1920) : Statistics ; M. O. Parthasarathy Iyengar : Fungi ; Dr. T. S. R. Seshadri (1900-1975) : Chemistry ; Dr. A. N. Khosla : Hydraulics ; Dr. Y. Nayudamma : Leather Chemicals ; J. N. Suri : Hydraulics ; N. K. Pannikkar : Oceanography ; Dr. M. S. Krishnan : Geology ; Dr. S. Bhagawantam : Physics ; Dr. K. R. Ramanathan : Physics ; Dr. B. V. P. Sreekantan : Cosmic Rays ; V. Ramalingaswami (b. 1921) : Medical Sciences ; D. R. Kaprekar (b. 1905) : Mathematics ; G. N. Ramachandran : Molecular Biophysics ; Homi Nusserwanji Sethna (b. 1923) : Chairman of the Atomic Energy Commisson, and Secretary to the Department of Atomic Energy, won the 'Shanti Swarup Memorial Award' for Engineering Science in 1960, was awarded the *Padmashri* in 1959, and the *Padma Bhushan* in 1966 ; Devendra Lal (b. 1929) : Geophysics ; C. N. R. Rao (b. 1934) : Chemistry ; K. K. Pandey (b. 1926) : Botany ; Govindjee (b. 1933) : Botany ; A. M. Chakrabarty (b. 1938) : Molecular genetics ; C. K. N. Patel (b. 1938) : Invented Carbon dioxide laser which generates a powerful light in the invisible infra red range, capable of sending messages over the earth and in space.

During the nineteenth century, although India grew more conscious of the impact of modern science on the life and society, yet there was very little scientific research done in the country. There were, no doubt, some brilliant Indian scientists who, for want of any well-equipped laboratory providing research facilities, could not continue their pursuits in scientific experiments, and hence, some of them were found to change their track of career.

Professor Ramachandra (b. 1821) of Delhi, was recognized as a man of science. He used to teach Mathematics in a Delhi College, and later in Roorkee. His treatise on the problem of 'maxima' and 'minima' was published in 1850. Dr. Aghore Nath Chatterjee (father of Mrs. Sarojini Naidu) was the first Indian Chemist to obtain D.Sc. degree (Edinburgh University) in 1883. He pointed out certain errors in the book on 'Stereochemistry' written by the famous Dutch Chemist, Prof. J. H. Vant Hoff. The author acknowledged his debt to Dr. Chatterjee in the second edition of his book. Unfortunately, this brilliant Indian scientist, unable to find suitable research facility existing in India, drifted towards administrative career. Similarly, Sir Ashutosh Mookherjee who began his career as an outstanding mathematician, took up law and later education as his career. He had contributed quite a few original papers on: Monge's differential equations, integral of Poisson, hydrodynamics, application of elliptic functions to problems of mean values etc. Dr. Ganesh Prasad, an eminent mathematician, remarked, "After Bhaskara, he (Sir Ashutosh) was the first Indian to enter into the field of mathematical research as distinguished from astronomical research, and did much which was truly original."

THE GOAL OF SCIENCE

It is, no doubt, that science has glorified the external man. In the process, it has denigrated the inner man to a great extent.

As science has taken the human race to a higher and greater region of life, but it has also indicated the path to destruction of human life and properties. The progress of science has created many new problems for security of mankind.

The atomic bomb that was dropped on Hiroshima, Japan on 6 August, 1945, immersed tens of thousands of people into instant death. It did worse, as it left thousands of people alive, who experienced death in life—deformed, deseased and half-dead.

Sankichi Toge (1917-1953) was one of those who survived the blast and later died at an early age. He composed a short poem on the Hiroshima massacre under the title 'Give Back My Father', which became a rallying cry for peace movements throughout Japan.

Give back my father, give back my mother,
Give grandpa back, grandma back,
Give our sons and daughters back !
Give me back myself, give mankind back ;
Give each back to each other !
So long as this life lasts,
Give peace back to us—
Peace that will never end !

Jawaharlal Nehru visited Japan and delivered a speech at a public meeting in Hiroshima on 4 October, 1957 condemning the historical inhuman destruction of mankind.

In spite of all its evil effects whatsoever, it must be admitted that the aim of science is to study nature and experience objectivity. The purpose of science is to provide knowledge and information for the welfare of mankind as a whole. But modern science and technology are said to discount the subjective aspect or the spirit in man. It views life in compartments. It fails to see life in full, life as an interdependent, comprehensive, integrated whole.

The science of nature must be informed by the science of man. Then only modern man's vision will be extended from machine to man, mind and spirit.

Dr. S. Radhakrishnan says: "When it is said that here are these things, the spectacular development of nuclear physics, the arms which we have produced and which threaten us with ultimate destruction, it will be noted, on the other hand, that we also feel a biological instinct for survival. It is necessary for us to overcome the temptations of these nuclear developments, and we must try to establish supremacy over them. They are not our masters. We discovered nuclear weapons. We, who discovered them, can use them for peaceful purposes and need not use them for self-destruction or the annihilation of humanity.

Let us remember that in this world there have been many civilisations, one after the other—Babylonian, Assyrian, Greek. When you look into the history of those civilisations, you will discover one fundamental fact : those which laid the stress on matter, on weapons, on arms, have passed away. Those which laid their stress on the development of friendship, love, brotherhood, have survived.

...If history has any lessons to teach us, it is this lesson, that nations which pledge themselves to peace and friendship, and which pledge themselves to use the greatest developments of science and technology for establishing human fellowship, it is such nations that have survived."

SAT

India had in the mid-sixties built a fairly complex and far-flung science and technology (SAT) system. In 1965, the government had established the Scientific Advisory Committee to Cabinet (SAAC) to advise the Cabinet on the formulation and implementation of science policy and on the coordination of scientific work among the various ministries and the scientific and technological agencies. Besides SAAC, there was a national Council for Scientific Research that was to develop a science budget in consultation with the different scientific agencies for approval of the government. Then a separate Ministry of Science and Technology was established with two sets of functions : (i) operational—responsibilities for CSIR (Council of Scientific and Industrial Research) and for the several surveys, such as the Survey of India, Geological Survey, Botanical Survey, and Zoological Survey ; and (ii) nodal responsibilites for science policy, scientific manpower planning, coordination of activities in different scientific sectors, and ensuring financial support for scientific activities.

Nehru's personal scientific outlook, his fascination with science and his close personal rapport with scientists contributed immensely to the science and technology (SAT) in India.

Mrs. Indira Gandhi, as Prime Minister, articulated issues and lines of thoughts which became incorporate into policy in order to make SAT system in India more effective. She brought literally the entire spectrum of science subjects in the government and under her own personal charge as Prime Minister : atomic energy, and space and electronics. She also appointed a scientist in the Prime Minister's secretariat, both for purposes of liaison with the scientific community and for providing advice on scientific policy.

As reards the SAT system in India, her three major accomplishments are :

(i) the experience and placing science and technology on a strong base ;
(ii) the rationalization of science and technology systems, and freedom granted to scientists and technologists in the matter of taking decisions ; and

(iii) the significant endeavour to advance research and development outside the government also.

Mrs. Gandhi saw science and technology as critical elements in India's modernization and development. She said in 1968 in the Indian Science Congress: "Technology is a key. It is a key to knowledge that opens the door to plenty as well as to power."

Again in 1970, she said: "The future of our society, its development and direction, is vitally linked with the activities of scientists and technologists."

She also said: "To me the greatest value of science is its liberating force."

India's science and technology policy has undoubtedly witnessed changes over the post-independence period. National security has been an elemental consideration in the evolution of economic and technological strategies. Here the 'salience' of national security arises not from any military tradition, rather the endeavour to make the country self-reliant and self-sufficient in all respects.

Prof. Abdus Salem, the eminent Pakistani scientist who won the Nobel Prize in 1980, has remarked, 'India will be science superpower in the year 2000.' He has perhaps considered that the major factor in India's possessing the third largest scientific community in the world was 'the cult of self-reliance', and that India has always been inclined to depend much more on her indigeneously manufactured equipments and components than the imported ones.

Science and Technology

Long after Copernicus, Galileo, Newton, Lavoisier, Darwin, Mendel, Pasteur and others, there have been many important contributions to add to the intellectual heritage of mankind. The great discovery of atomic fission was not published until 1939. The advances in science in the last half-century have mainly been confined to nuclear physics. The first practical digital computer was invented during World War II. The discoveries in solid-state physics have revolutionized computers, phonographs, TV sets etc. The discovery of penicilin and the many antibiotics have benefited modern medicine. Lasers are used in many situations, for eye surgery, for drilling holes in diamond and saffires and in a multitude of ways. But the greatest intellectual revolution has taken place in biology.

If our universities demanded growth of interest in science from their students, the high schools have to emphasize the importance of working toward better preparation in sciences and mathematics. If scientists try to teach non-scientists molecular biology without chemistry, or to teach quantum theory without mathematics, they are unlikely to succeed. So science has to be introduced in the educational programme from the very beginning of studies.

The contributions of science had been remarkable during World War II, and the economic battles that lay ahead would also require a major effort in research and development. A country cannot prosper without sustained investment in science and engineering education and research in the universities. Those nations that have attained an economically dominant position are most anxious to safeguard their pre-eminent position in science, technology and industrial excellence while maintianing their defence preparedness at as high a level as possible.

Any country that wishes to remain competitive in the modern world must do three things : (i) it must support basic research ; (ii) it must educate new scientists and engineers ; and (iii) it must invest adequately in research facilities and equipment.

Basic research produces knowledge that is available to all (not just the organization that pays for the research). Investment in science and engineering has been the source of much of our economic progress over the past four decades. It continues to be the best single way that we can provide the jobs and that national wealth we must have in decades to come. Our science and technology can provide the means to meet the challenge of international economic competition in the decades ahead.

The most basic considerations of national welfare demand that we do no less.

Technology is a part of our intellectual heritage and is an intrinsic component of our society. Technology is power in the modern context and it will be difficult to redirect its course. The intellectual conception of technology, rooted in Aristotelian definition of man conceived as a rational animal, emphasizes the abstrat cognitive elements in the make-up and the development of man.

In science, we investigate the reality presented to us, the empirical reality, the world around us. In technology, on the other hand, we create a reality according to our designs : this is the man-made reality. Our scientific pursuits are 'what there is' : and our technological pursuits are based on our ability to construct objects according to our desires. Science concerns itself with 'what is', whereas technology is concerned with 'what is to be'.

In science, we have reality first and then its description ; whereas in technology, we have description or design first, and only afterwards reality. The process of establishing correspondence between reality and its description in science is known as establishing the truth. The vital characteristic of technology is to attempt to turn the technically possible into the technologically possible.

Technology is thought of as applied science. Scientific theories produce basic explanations about nature, and technology derives practical applications from science. The production of electricity from nuclear energy is one such instance.

Technological advance of the late nineteenth and early twentieth centuries developed independently, without scientific research and understanding preceding them. Before fundamental principles of thermodynamics and aerodynamics were understood, the steam engine, the automobile and the aeroplane were developed. Nevertheless, these stray technological landmarks have no validity in the present age, as science and technology have very close interaction.

Science and Technology have only a peripheral role in meeting basic needs, and all Indian planning from the very beginning was made with the nationalistic view of achieving self-reliance in science and technology. Self-reliance is the goal in Indian economy as a whole, in the areas of food, energy, defence and what not? It was the purpose of SAT planning to subserve this central aim of technological self-reliance and self-sufficiency. In the approach of SAT planning there was the principle of relating the supply of science and technology to use them efficiently to fulfil national goals.

Science and Society

Science and society influence each other. If any nation is to be profited by science, it must ensure strong neutral interaction and active interfaces between science and society. Popularization of science is a crying need in any part of the world, and more so in India with 70 per cent of her people being illiterate. Today every Indian must be made to understand the revolutionary changes in human civilization ushered in by the impact of modern science. The scientific knowledge will help them in improving agriculture, health, industry and commerce. Rural scientific laboratories should be established in different centres in the country to educate the common man in health programmes, agricultural progress and development etc.

National economy is inseparably related to science and technology. A nation is bound to prosper in agriculture, industry and commerce with the growth of indigineous productivity of science. Hence more scope should be made available to the people for proper scientific and technological education and research.

NUCLEAR ENERGY PROGRAMME

Conception

The Nuclear Energy Programme in India originated from the conviction, determination and drive of a dedicated individual, Homi Jehangir Bhabha. He who was endowed with a rare imagination and strange vision, thought even before the explosion of atom bomb and consequent demonstration of uncontrolled release of energy, that the energy possessed by atom was controllable. At that time, exploitation of atomic energy was restricted only amongst a few scientists in the U.S.A., U.K. and Canada. Still Bhabha could foresee the importance of peaceful use of the atom. In 1944, he requested Sir Dorabji Tata Trust, Bombay, for the establishment in the interest of the country, of an institute for fundamental research in the fields of physics and mathematics. His request was accepted, and in 1945 the Tata Institute of Fundamental Research was founded in Bombay.

Although Bhabha himself was a theoretical physicist, yet he gave considerable support to all experimental technique at this Institute. In 1952, a few important instruments were constructed. namely, a cyclotron, a Van-de-Graaff machine, a linear accelerator, a mass spectrometer, beta ray spectrometers, cloud chambers, multi-channel analysers, nuclear detectors, and also a host of other electronic instruments needed to support nuclear research.

The Atomic Energy Act was passed on 15 April, 1948, and the Atomic Energy Commission was set up in August, 1948 with Bhabha as its Chairman. The task assigned to the Commission included the survey of the country for minerals of interest for a successful atomic energy programme, training of necessary technical and scientific personnel to carry out development of nuclear technology and encouraging research in its own laboratories and other institutions. To implement the aims of the Commission, there was need to build up teams of chemists, metallurgists, biologists, physicists, nuclear engineers and of other various disciplines.

In January, 1954 the Atomic Energy Commission decided to set up at Trombay near Bombay, a separate institution called the Atomic Energy Establishment for research in and development of peaceful uses of atomic energy. In 1967, the centre was, however, renamed Bhabha Atomic Research Centre (BARC) to perpetuate the memory of the great scientist, after his death.

Sources of Energy

Nature provides a variety of sources of energy, some of which have been utilized by us, and some not. Among them, some may be mentioned as (1) firewood, dung and wastes, (2) solar energy, (3) energy contained in winds, (4) tidal energy from the ocean, (5) geothermal energy stored in the interior of the earth, (6) hydro-electric power, (7) nuclear energy. Of these, the first category has been known to man for ages. The next four still remain as not properly used. Hydro-electric power has been utilized to some extent through several multi-purpose river valley schemes.

Nuclear Energy

Any kind of matter is made up of a few basic elements which are again made up of what are known as 'atoms'. An atom possesses all characteristics of the element. It has a size of the order of 10^{-8} cm. and a weight of nearly 10^{-23} to 10^{-21} gm. Substances like hydrogen, copper, lead etc. are all made of these atoms. Some of the atoms of an element are higher or heavier than the typical atom. Hydrogen, for example, exists with three types of atoms whose weights are in the ratio of nearly 1 : 2 : 3. The reason for this is to be found in the internal structure of the atom. The atom has a small charged core in its centre, called nucleus, of size nearly 10^{-13} cm. consisting of smaller particles known as 'protons' and 'neutrons', around which there remains an electronic cloud. The proton and the neutron are the elementary nuclear particles having similar masses, nearly that of the hydrogen atom itself but possessing different electrical changes. The proton has a unit position charge, whereas the neutron is electrically neutral.

The different species of hydrogen atoms consist of one proton but different numbers of neutrons, the three species consisting of 1 proton plus 0 neutron, 1 proton plus 1 neutron, and 1 proton plus 2 neutrons. Atoms which differ from each other in the number of neutrons, but which possess the same number of protons are known as 'isotopes'. The isotopes of hydrogen are named as hydrogen, deuterium, and tritium. Such a nomenclature to identify isotopes does not exist for isotopes of other elements. Symbolically, one represents the isotope of an element by $\frac{A}{Z}X$, where Z is the number of the protons, A the number of protons plus neutrons, and X the symbol of the element.

As the neutron is electrically neutral, it can penetrate the core of the atom without difficulty. A neutron which is the thermal equilibrium with any condensed system at room temperature possesses an energy of nearly 0.025 ev (1 ev is of 1.6×10^{-12} erg ; $1\text{McV} = 10^{6}$ ev). The energy released by fusion neutrons is uncontrollably large. This fact was known to the whole world long ago, from the first public demonstration of large scale release of atomic energy through atom bomb to devastate Hiroshima and Nagasaki in Japan. The entire mankind got frightened of such a terrible and inhuman destruction.

During the early forties, a group of physicists under the leadership of Enricho Fermi set up a nuclear reactor to control the chain reaction from a run-away condition. This was the first attempt to harness the atom for peaceful purposes.

Harnessing the atom in India initially needed the building of various instruments, plants, and technologies. Electronics instrumentation, nuclear detectors, nuclear instrumentation, uranium metal extraction, uranium fuel fabrication, radio-chemical techniques, fuel processing plant, and vacuum technology are some of the aspects of the project which grew slowly and steadily around certain small groups. The momentum generated by a 'growing science' could not be contained within the physical limitations of BARC.

In 1948, the Atomic Energy Commission was conceived to develop, control and use atomic energy for the welfare of the people of India, by producing and supplying electricity without causing radiation hazards and also ensuring the safe disposal of radioactive wastes.

The Department of Atomic Energy was established in 1954 backed by premier institutions, such as Bhabha Atomic Research Centre (BARC) for research and development ; Atomic Minerals Division (AMD) for prospecting nuclear energy sources; Uranium Corporation of India Limited (UCIL) for processing uranium ore ; Nuclear Fuel Complex (NFC) for fabricating reactor fuel ; Indian Rare Earths Limited (IREL) for processing thorium and zirconium ; Electronic Corporation of India (ECIL) for instrumentation and control systems ; Heavy

Water Division (HWD) for production of heavy water; Waste Management Division (WMD) for treatment of radioactive waste; Power Reactor Fuel Reprocessing Division (PREFRE) for reprocessing the spent fuel with Indian consulting and design and manufacture of every major component indigenously.

It was felt that the development of an important technology like atomic energy in the country needed the creation of a cadre of scientific and technical personnel who should be capable of executing, planning, and advising on various aspects of the national programme. Hence Bhabha thought of a training scheme for orienting first class graduates from universities. The training school was established in 1957. About 200 graduates in science and engineering from all over the country were recruited for training every year. They were taken through a broad-based programme in nuclear science and engineering, equipping them to adapt themselves to the work in any of the areas they were assigned. The training school had been under the personal care and supervision of Raja Ramana. In course of time, the training school was found to contribute to more than 50 per cent of the total number of scientists and engineers at BARC.

BARC has also collaborated with a large number of neighbouring developing countries like the Philippines, Thailand, Korea, Taiwan and Indonesia, by sharing its experience in several fields like solid state research using neutrons, reactor operations etc. through bilateral, regional, and international agreements.

Thermal Reactor

Reactors utilizing fission of uranium 235 with slow neutrons are called 'thermal reactors'. If natural uranium is used as fuel in such reactors, the active material is the uranium 235 content of it. These reactors generally use heavy water as moderator and water, heavy or ordinary, as coolant. The majority of thermal reactors in the world, use enriched uranium as fuel. The enriched fuel is prepared by removing uranium 238 from natural uranium by a very elaborate and complicated process, thereby making it richer and richer in its uranium 235 component.

India's first research reactor 'Apsara' was built indigenously and commissioned in Trombay in 1956, in which the enriched uranium fuel elements for the reactor was obtained from U. K. Atomic Energy Authority.

India's second research reactor 'Cirus' was a gift from the Canadian Government under the Colombo Plan. It was also installed at Trombay. The uranium metal plant and fuel fabrication facility at Trombay were set up in 1959 for fuelling this reactor.

A zero-energy reactor 'Zerlina' was set up with indigenous expertise in 1961 (later decommissioned in 1983).

In fact, India took her first step in reactor technology when a zero-energy fast reactor 'Purnima' consisting of plutonium oxide fuel elements with molybdenum, copper, and steel reflectors, was set up at BARC in 1972. And India's first reactor using uranium 233 as the fuel became operational on 10 May, 1984. It was named 'Purnima-2'. It is the only reactor in the world at present with uranium 233 fuel. The reactor core contains uranyl nitrate solution in water. Betyllium Oxide is used as reflector of neutrons.

The latest research reactor 'Dhruva' built at Trombay, is 100-megawatt heavy water cooled and moderated reactor which is fully designed in India.

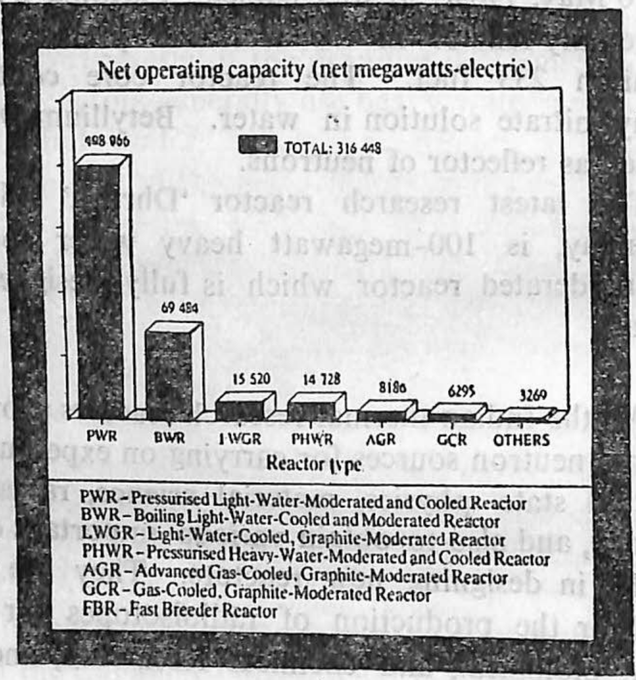
All the Indian thermal research reactors provide intense neutron sources for carrying on experiments in solid state physics, material science, radiation biology, and also to obtain various important data needed in designing new reactors. They are also used for the production of radioisotopes for nuclear, biological, and chemical researches, and of course, for clinical and therapeutic purposes.

India is now completely self-reliant in all aspects of fuel technology: mining, processing, and fabrication in finished forms for use in the reactors.

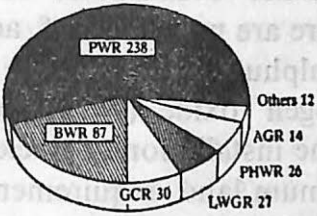
Reactors :

Nuclear reactors are classified according to the fuel, coolant and moderator used to support the nuclear chain reaction. There are mainly five types of reactors :

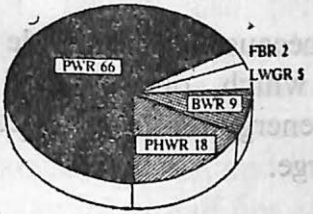
Pressurised Water Reactors (PWR) : Boiling Water Reactors (BWR) ; Pressurised Heavy Water Reactors (PHWR) ; Gas Cooled Reactors (GCR) ; and Liquid Metal Cooled Breeder Reactors (LMBR).



There are *434* units in operation in 26 countries with a capacity of 316.000MWe and 100 units under construction with a capacity of 80,000MWe. Type-wise distribution is as follows :



Units in operation (434)



Units under construction (100)

Courtesy: International Atomic Energy Agency (Vienna)

Electricity Generation :

Many of the countries in the world depend on nuclear power significantly for their electricity generation. At present about 17% of the world's electricity is generated through nuclear sources. For example, Japan, inspite of the trauma of Hiroshima and Nagasaki in 1945, as well as its generally high seismicity, has as many as 38 nuclear plants generating 30,000MWe. USSR, even after its 1986 Chernobyl accident continues to operate 56 units producing 33,000MWe. And USA, despite its 1979 mishap at Three Mile Island has 110 units in operation giving 1,00,000MWe.

Nuclear source is clean, compact and concentrated.

Clean—for minimal impact on the environment, compared to other commercial energy generating sources. There are no effects of acid rain due to emission of Sulphur dioxide (SO_2), Carbon dioxide (CO_2), Nitrogen oxide (NO_2), or heavy metal pollutants. The installation of nuclear power plants involves minimum land requirement and minimum displacement of local populace.

Compact—because it is available in the form of fuel bundles, which, once loaded in the reactor core, provide energy for 1½ to 2 years at a stretch before discharge.

Concentrated—as one kg uranium gives energy equivalent to 25,000 kg of coal even at 1% utilization in today's first stage thermal neutron reactors. This can be stepped up to 60 to 70% utilization in breeder reactors. That means, one kg uranium would give energy equivalent to two million kg of coal. And for India, it represents an additional generating source of electricity. Hydel and coal resources not being evenly distributed geographically, nuclear sources help overcome this limitation. Nuclear power plants can be installed in locations even remote from hydel and coal resources. In 1948, the Atomic Energy Commission was conceived to develop, control and use atomic energy for the welfare of the people of India, by producing and supplying electricity without causing radiation hazards and also ensuring the safe disposal of radioactive wastes.

A Three-stage Programme in India

India has planned a three stage programme to benefit from the atom. *In the present first stage,* PHWRs use natural uranium fuel to produce electricity, plutonium fuel with 96% unused uranium (U238). The use of Fast Breeder Reactors *in the second stage,* with plutonium as fuel which will generate electricity and more plutonium from U238, kept as a blanket. It will also produce uranium 233 fuel from thorium, used as blanket material. *In the third stage,* U233 will be used as fuel and thorium as blanket, producing more U233 fuel than the fuel consumed in fast and thermal reactors. Helping us to make full use of our abundant thorium deposits *to produce electricity for centuries to come*.

Inspite of the all-India nuclear contribution being a mere 2·6%, at state level as in Rajasthan and Tamil Nadu, it has been as high as 40%. That is why, although in the final analysis, nuclear power will contribute to just 10% of the total electrical capacity by 2000 A.D., yet India's 70 reactor-years experience has helped her considerably in improving the design of each of her successive power stations from Rajasthan to Madras to Narora. The Narora plant is the fore-runner of the standardized design, for all up-coming projects are greatly reducing unit gestation period to about eight years.

In order to achieve a better standard of living today and to conserve the dwindling energy reserves for future generations, India would need an optimal

INDIA'S NUCLEAR POWER PROGRAMME UPTO 2000 A.D.

	Station Capacity MWe	Cumulative MWe	Year of Commissioning (In service)
OPERATIONAL UNITS			
TARAPUR-(BWR)—1 & 2	2×210	420	1969
RAJASTHAN—1 & 2	2×220	860	1973, 1981
MADRAS—1 & 2	2×235	1330	1983, 1985
NARORA—1	1×235	1565	1990
UNDER CONSTRUCTION			
NARORA—2	1×235	1800	1991
KAKRAPAR—1 & 2	2×235	2270	1991, 1992
KAIGA—1 & 2	2×235	2740	1995, 1996
RAJASTHAN—3 & 4	2×235	3210	1995, 1996
UNDER SANCTION			
KAIGA—3, 4, 5 & 6	4×235	4150	1996-1997
TARAPUR—3 & 4	2×500	5150	1997-1998
RAJASTHAN—5, 6, 7 & 8	4×500	7150	1998-2000
PLANNED			
KUDANKULAM-(PWR—1 & 2	2×1000	9150	1998-1999
NEW PROJECTS	6×500	12150	1998-2000

mix of thermal, hydel and nuclear sources for fuelling growth of her needs. And hence India has just one major overriding goal : to harness the power of the atom, and to achieve self-sufficiency in power generation for generations to come.

SPACE RESEARCH

In India, space research, including space science and technology, has been a long tradition. India's space research is noticed between 1780 and 1790, when the Nungambakkam observatory in Madras initiated a new phase of study in the field of climatology associated with metereology, weather prediction, and allied subjects. The Madras astronomical observatory undertook studies in the fields of astronomy, geography, and navigation in India by systematic metereological observations beginning around 1796. In 1823, Colaba observatory in Bombay was established for astronomical and magnetiç studies. In 1835, the Survey of India in Calcutta began to work on geographical phenomenon. Trivandrum observatory founded in 1836, expanded the scope for astronomical and metereological studies. In 1841 geomagnetic studies commenced in Simla. Another observatory was installed in 1852 on the summit of Agasthyamalai near Trivandrum at an altitude of 6,200 ft. above the sea. This observatory facilitated the study of the effect of altitude on magnetic and metereological elements. These data were necessary to verify theories of semidiurnal oscillation of the tropical atmosphere.

The Agra observatory in 1869 further widened the scope of studies of metereological-cum-climatological subjects in the country. In 1875, the India Metereological Department (IMD) took up the work of co-ordinating the metereological studies reported from various centres. And the establishment of a solar physical observatory at Kodaikanal in 1899 promoted the study of astrophysics.

In course of research, it has discovered that fluxes of gases flew out from the regions above sunspots. This discovery encouraged those Indian space scientists who had been dealing with astrophysics, solar-terrestrial physics including ionosphere, solar radio astronomy, solar X-rays, solar cosmic rays, and geomagnetism involving also studies on the interaction of solar radiation on the upper atmosphere.

Systematic scientific studies on the mutual interaction of radio waves and the upper atmosphere began in 1925, when the University of Calcutta founded a wireless laboratory.

India's promotion of space research has always been for peaceful purpose, and to promote international co-operation in the field.

The growth of space research activities during 1965–75 was brilliant. By the end of 1965, TERLS had made seventeen sounding rocket launchings, and during 1966 there were eleven more sounding rockets launched.

The principal objectives of India Space Research

Organization (ISRO) are : (i) application of space science and technology to further national goals in mass communication and education via satellites and also the survey and management of natural resources through remote sensing technology from space platform ; (ii) development of space technology in India with the maximum degree of self-reliance to further the aforesaid applications in the matter of design, development, and fabrication of sattellites and rocket systems with their related tests and operational facilities ; and (iii) utilization of the spin-offs from developments in space research in other fields of research, industry, education, and related areas.

Thus the activities of ISRO are aimed at achieving developments in space science and technology for the socio-economic progress of India.

Space Exploration

Space research has opened up a new dimension in man's study of the universe. Astronomers can now photograph in close-up the Moon and the planets. Astronomy is undergoing a revolution, and space satellites has today made it possible to detect radiation from outer space at wavelength, formerly out of range. Most spectacular of the new objects being studied are the pulsing, bursting, and enrupting sources observed by X-ray satellites, caused as matter pours from ordinary stars on to small, compressed Neutron Stars, or in some cases, Black Holes orbiting them.

Space Race

Sir Issac Newton (1642–1727), first of all, propounded the space flight in his book 'Mathematical Principles of Natural Philosophy'.

The First Sputnik

The spece age actually began on 4 October, 1957 when Russia launched *Sputnik-1* into orbit, and this was followed a month later by *Sputnik-2* which carried the dog *Laika*. Measurement of the animal's heartbeats, temperature and other reactions, radioed to Earth, suggested that human beings might also survive prolonged periods in space.

The first US satellite, *Explorer-1* did not follow until 31 January, 1958, but its instruments made the first major discovery of the space age—the Van Allen radiation belts around the Earth, where electrons and protons from the Sun are trapped by the Earth's magnetic field. Soon after, probes were sent to explore the Moon and planets, and on the way they detected the *Solar Wind* of sub-atomic particles streaming from the Sun.

Mankind's first look at the Moon's far side came with the pictures from the Russian *Luna-3* in October, 1959. The US *Mariner-2* in 1962 flew past Venus, confirming both its high temperature and the reverse direction of its rotation which had been guessed by astronomers beforehand. *Marina-4* sent back remarkable photographs revealing craters of Mars. The work of the early space probes has been extended and improved by later planatory explores, culminating in remote-controlled landings on the Moon, Venus and Mars — the last in a search for the possibility of life.

Probes are now swooping closer to the Sun than ever before to study solar activity, while others are pushing the boundaries of exploration out to Jupiter and beyond. Plans are also being made for a deep probe to intercept one of those ghostly wanderers of the solar system — the comets.

Manned Mission

The first man to be launched into space was the Russian Yuri Gagarin who orbited the Earth once on 12 April, 1961. Later, Russian cosmonauts, including first space woman, Valentina Tereshkova (16 June, 1963) were able to stay in orbit for upto five days.

American astronauts made more modest flights in their smaller *Mercury* spacecraft, but in 1965 they began the series of two-man *Gemini* flights that overtook the Russian lead in the space race. The team of astronauts in the 'Gemini' programme practised rendezvous manoeuvres, docking procedures and space walks in preparation for the coming *Apollo* missions to the Moon.

In a *Gemini* capsule the astronauts had less space than in the front of a small car. The three-man *Apollo*, however, was relatively roomy, with sufficient space for the crew to move about and even to stand upright. The vital part of *Apollo* so far as landing on the Moon was concerned, was the four-legged *Lunar Module*, in which two men touched down on the Moon. The first Moon-landing, by Neil Armstrong and Edwin Aldrin from *Apollo-11*, took place on 21 July, 1969.

Exploring the Moon

A total of 12 Americans walked on the Moon during the Apollo programme, bringing back 380 kg of rocks and soil. These samples from the Moon, along with scientific measurements made on the surface and from the orbiting 'mothercraft' have helped scientists to piece together a detailed picture of our nearest neighbour in space.

A manned flight to Mars is now being planned. NASA scientists announced in October, 1985 that Mars has sigficantly more water than was once thought and is still undergoing seasonal changes similar to those on Earth.

Experiments in Space

In the *Skylab* space station, and its smaller Russian counterpart called *Salyut*, astronauts began to extend the surveys of Earth resources and astronautical observations begun by satellites. The three *Skylab* crews, each of the three men, brought back a total of 72 km (45 miles) of magnetic tape logging instrumental results, 46,000 Earth's resource pictures, and 1,75,000 image of the Sun taken through the special Skylab solar telescope.

Space Stations allow scientists and engineers to take advantage of the conditions of weightlessness and total vacuum when developing new manufacturing processes. Without gravity, for example, perfect crystals can be grown of materials for electronic components such as transistors. Materials that do not mix under gravity, for example, oil and water, form a perfect blend in weightlessness. Metals can, therefore, be fused, then cooled and solidified to make new alloys unattainable on Earth. Space conditions can also be used to produce ultra-pure chemicals such as vaccines, or make possible studies of cell growth that may throw new light on biological malfunctions such as cancer.

Space Shuttle

In USA, a new transporation scheme called 'Space Shuttle' is rapidly developing so that the cost of space launches can be brought down. The Shuttle's main component is a re-usable spacecraft, the orbiter, which is launched by means of rockets, but can be caused to glide back to Earth like an aircraft landing on a runway. The winged Shuttle Orbiter is the size of a modern jetliner, with a cargo bay 18.3 m. (60 ft.) long and 4.6 m. (15 ft.) wide, which can carry up to 29.5 tonnes into orbit. The Shuttle can, therefore, launch several satellites at a time and bring others back to Earth, if necessary, for repairs.

Each Shuttle Orbiter will be re-used upto 100 times, largely replacing conventional rockets which can be used once only. The first Shuttle Orbiter

'Columbia' reached orbit with a crew of two, successfully in April, 1981—the twentieth anniversary of man's maiden trip to space. Shuttles named *Columbia*, *Challenger*, *Discovery* and *Atlantis* achieved many firsts in space exploration and research. Shuttle *Challenger* took Sally Ride, the first US woman, to space on 18 June, 1983. The first night flight launched on 20 August, 1983, carried also America's first black, Guion S. Blueford, who performed space exercises under the eye of Space Physician William Thornton.

Atlantis, the fourth and final member of the NASA's Shuttle fleet was launched on 3 October, 1985. It deployed to bomb-shielded jam-proof Air Force Communication Satellites.

Space Repair

In November, 1984 Shuttle succeeded in retrieving two malfunctioning Satellites, namely *Palpa B-2* and *Wester-6*. These satellites could be used again. Prior to this, in April, 1984 Shuttle made successful retrieval and repair of Satellite *Solar Max*. For this historic feat, astronauts had to get out of the Spacecraft and walk on space for as long as 6 hours and 44 minutes.

Discovery completed a secret military mission on 28 January, 1981 when it launched the first of the four Spy Satellites against Soviet Union, called *Signit* (Signal Intelligence). These reconnaissance satellites will peep into Soviet territory day and night. They can sense the movement of even a small vehicle in the dead of night.

'Challenger' Tragedy

The American space programme received a set back on 29 January, 1986 when their Space Shuttle *Challenger* exploded in mid-air, 75 seconds after lift-off. The crew, six astronauts and a woman school teacher named Christa Macauliffe were all dead.

After 25 years of space exploration and 55 missions, the US faced space history's worst disaster.

Challenge tragedy was a set back not only for the US, but also for many other countries including India which had programmed multi-purpose satellites to be launched by the US Shuttles.

Mir Station

On 20 February, 1986 the Soviet Union launched a new orbital space station called *Mir* (peace) described as a third generation space laboratory, from Baikonur Cosmodrome in Kazakhstan. It joined the *Salyut-7* space station that has been in orbit around the Earth since April, 1982.

Mir is a multi-modular station which can accomodate six spacecrafts at the same time. Two Soviet cosmonauts were launched to space on *Soyuz T-15* on 13 March, 1986 for a rendezvous with *Mir*. The craft docked with the space station the next day. For the first time in the Soviet space history, the entire launch was televised live throughout the world.

The *Salyut* crew, Leonid Kizim and Vladmir

Solovyov, conducted several experiments including flying from one space station to another. They flew to *Salyut-7* from *Mir*, spent 50 days on board and flew back successfully.

Both the Soviet stations have orbits on the same plane some 3,000 km apart but the Shuttle takes more time than a trip either way with Earth, because the spaceship *Soyuz* uses the laws of the celestial mechanics — changes orbits, for the Shuttle in manoeuvres designed to save fuel.

Salyut-7 is in near-earth orbit for four years, during two of which it has been manned by nine crews including an Indian named Squadron Leader Rakesh Sharma, and a French cosmonaut.

Both the Soviet cosmonauts returned to Earth safely on 16 July, 1984 after 125 days in space.

Indian Space Programme

Indian Space Programme is directed towards harnessing space technology in a self-reliant manner for : (i) satellite communications including direct TV/Broadcasting to community receivers ; and (ii) natural resources survey and management including environment monitoring and meteorological forecasting. To achieve these ends, India is actively involved in developing and operationalizing a series of satellite and launch vehicle systems.

Indian Space Programme began with the setting up of a sounding rocket launching facility at Thumba near Trivandrum in 1963. The Thumba Equatorial Rocket Launching Station (TERLS) which in 1968 was dedicated to the United Nations Organization, served as the nucleus for the growth of Indian Space Research Organization (ISRO) which today encompasses a number of centres.

The Department of Space (DOS) located at Bangalore is responsible for the execution of India's Space activities through ISRO.

India's Spacecraft

Indian Space Programme took a major step with the launching of the first indegineously built spacecraft, *Aryabhata*, in 1975, This 360 kg satellite, designed to acquire the basic expertise in satellite technology, was placed into orbit from the Soviet Union by a Soviet rocket carrier.

Aryabhata was followed by *Bhaskara-I*, an experimental earth observation satellite. It was landed in 1979. It carried TV camera and microwave radiometer payloads for Earth observation studies in hydrology, forestry, snow melting and oceanography. An improved model of this satellite, *Bhaskara-II*, was launched in 1981.

In the area of satellite communication, ISRO conducted two large-scale experiments relevant to India's communication needs. Through Satellite Instructional Television Experiment Project (SITE) during 1977–79, developmental programmes were telecast direct to community receivers in 2,400 villages, using American satellites.

India also took steps for building her own first 'satellite launch vehicle', *SLV-3*. The four-stage solid propellant *SLV-3*, during its three successful flights in 1980, 1981 and 1983, orbited Indian-built *Rohini* series of satellites.

In June, 1981 India's first experimental geostationary communications satellite, *APPLE*, was successfully launched aboard the European Space Agency's *Ariane* launch vehicle from Kourou in France Guyana. During this satellite's active in-orbit for 27 months, it was used to conduct a variety of advanced satellite communication experiments. It also provided live TV coverage of selected national events.

The successful launching of *INSAT-1B*, a multi-purpose domestic satellite, on board the American Space Shuttle in 1983, and its operationalization have given India the capability of country-wide domestic telecommunications, meteorological benefits and direct community telecasting.

The *SLV-3* project provided India with the expertise for embarking on the development of large and more sophisticated launch vehicles. To meet the payload requirements of the Augmented Satellite Launch Vehicle (ASLV) designed to orbit 150 kg satellites and a Polar Satellite Launch Vehicle (PSLV) capable of injecting 1,000 kg class satellites into a polar sun-synchronous orbit, ISRO has developed a series of 150 kg spacecraft called *Stretched Rohini Satellites Series* (SROSS) covering selected missions in the areas of scientific research, technology and remote sensing.

Sounding Rockets

ISRO had developed and qualified a series of Sounding Rockets like RH-125, RH-200, Centre, RH-300, RH-560 etc. for meteorological and upper atmospheric research. RH-560 is India's largest Sounding Rocket capable of reaching an altitude of 360 km with a 100 kg payload weight. Flights are regularly conducted from India's three Sounding Rocket Ranges at Thumba, Sriharikota and Balasore.

India attaches great importance to cooperation with other countries and international agencies, most prominent among them being USSR, USA, UK, France, FRG (Federal Republic of Germany), the European Space Agency (ESA) and the United Nations.

As part of ISRO's cooperation with industry, many technological processes developed by ISRO in the areas of electronics, chemicals and materials, have been transferred to Indian industries for commercial production.

India Enters the Space Age

India triumphantly blashed itself into the space age on the historic day of 19 April, 1975 when her own satellite *Aryabhata* was successfully launched at an altitude of 622 km, to keep circling the Earth. The diamond-shaped, 26-faced blue and violet spacecraft, 147 cm in diameter and 111 cm in height, and weighing over 360 kg, was wholly designed by Indian scientists and engineers at the Space Research Centre at Banglaore.

Aryabhata encircled the globe every 96.41 minutes as an explorer of atmosphere and outer space, and the data transmitted by it was received by three tracking stations located at different parts of the country — at Sriharikota near Madras, in Moscow, and at a space centre in France. Fittingly named after India's Golden Age astronomer of the fifth century A.D., Aryabhata, of the court of Emperor Vikramaditya, the satellite conducted three vital and unique experiments simultaneously ; one of which was concerned with the detection and study of X-ray emission from outer space ; the next one related to the study of solar neutrons of gamma rays emanating from the sun ; and the third one involved the detection and study of the presence of suprathermal electrons and the ultra-violet background at the F-region of the ionosphere.

The chief significance of the *Aryabhata* experiment is that India could command, control and communicate with its satellite from its ground station. *Aryabhata* was the heaviest satellite lofted into space, which type was tried by no other nation in its maiden attempt.

India thus joined the prestigious and proud elite of ten world nations which have their own satellites circling round our planet Earth.

Indian scientists, engineers and technicians had demonstrated and proved the ability and prowess by setting off a unique underground non-proliferating nuclear explosion at the Pokhran range of Rajasthan in 1974. If we are able to execute perfect explosion technique, we may also be able to find water and oil in abundance from under the ground. Besides, the nuclear energy itself could be harnessed as power. The satellite can unfold to us the secret of harnessing solar energy and ordering rains at will.

Moreover, exploding of the atom and orbiting of the satellite have also great significance in safeguarding India's security and integrity. The nuclear powers will no longer be able to blackmail us, dictate terms to us, or compel us to toe their lines. With the nuclear bomb and satellite system, we can talk to them on equal terms. India must grow from strength to strength and cover herself with success, prosperity and glory.

COMPUTER SCIENCE

Now-a-days computers seem to have a wide range of uses and play an ever-increasing role within our society. Many of the activities in today's society are performed by computers.

What is a computer ? The Computer is an electronic machine which can execute a job at high speed (in millionth and billionth of a second). Computing has something to do with reckoning or calculation, as a man has been using his brain for centuries to do just the same thing. It is true that man has so long invented or discovered for centuries many wonderful things—all without computers. What is the special about them that we need computers today ? It cannot simply be, because they are calculating devices. We have such devices, such as pocket and desk calculators which are cheaper and easier to use than computers.

The World War II dedicated and pressurized research in many areas. For the use of night bombs, submarines, and range missiles on ships and tanks—the targets—which could not be seen by any means during the night, and therefore aimed with accuracy, a sort of system of firing tables with detailed mathematical calculations was needed, and hence a machine was to be manufactured that could accurately produce tables for such operations. In 1942 the Ballistic Research Laboratory of the US

Army Ordnance Department began work with the Moore School of Electrical Engineering, and finally a computer named ENIAC had been made in Fubruary, 1946, which was able to produce the tables by carrying out the huge number of calculations involved, accurately and speedily, because it was electronically devised.

Before World War II the computer also evolved as a result of man's research for fast, accurate calculating devices, but there were three kinds of simple calculating devices : mannual, mechanical and automatic. During the late nineteenth and early twentieth centuries the 'punched card' tabulating systems were developed. Another common medium for communicating with the computer was 'paper tap' which had been in use for many years before the invention of computer.

Punched Card input was once the traditional form of communicating with computers. The standard punched card used with computers is divided into 80 columns and 12 rows, providing a maximum of 80 characters per card.

The paper tape can be found on old pianola rolls. It was used by typesetters (the Monotype process). Computer tape is normally 1 inch wide, comes in rolls, and may be used in any length upto several hundred feet. Information is recorded as holes punched in rows across the width of the tape, with one row representing one character. Tapes make use of different codes depending on the number of channels.

The paper tape reader operates in a similar manner to the cord reader. Paper tape, like punched card, is not now so widely used. Certain teleprinter terminals use paper tape to record the input of date or programme results. Paper tape attachments for recording data are also found to be associated with a number of business machines, namely various types of accounting type machines and cash registers.

Extensive Use

The problems which the earlier computers had to solve were mostly mathematical. But today computers are used to forecast weather, to operate machines to cut shapes of sheet metal, and even to guide spacecraft to the moon. They can set and print newspapers and books. They can be used to help diagnosing diseases and to find out whether a hospital bed is available for a particular patient. They are used to find obscure documents in archives and elusive criminals on the run. The offices use them for accounting, invoicing, stock control, and payrolls. The railways and the air companies around the world relay on them to book seats or rooms in hotels either today or a year from now.

The original idea for inventing computer was to create a fast calculating machine. But with the development of science, the major computing performances today include the applications of a nonmathematical or non-numerical nature. Today the modern computers act upon information. This information or data comes in all shapes and sizes, from a mathematical equation to the required details about a company's work-force, the detailed data to project craft through space, and thus it is now the science of information processing—recording, manipulating and retrieving information.

Nature of Information

As human beings, we continually make value judgements about the information, we receive and instinctly process. A particular piece of art, whether a painting, piece of music or whatever it may be, will attract some people, but it may repel others, because human judgement is based on one's feelings, taste, knowledge and experience. But computers cannot make such judgements. They are devoid of emotions. A computer can be programmed (instructed) to generate poetry or music, but it cannot judge its quality. Computers have no feelings and no instincts like human beings. They are machines. They can help mankind, but they do not threaten it. They are as good as man makes and uses them.

Information is handled in the computer by electrical components such as transistors, integrated circuits, semi-conductors, and wires.

Computers are classified as super, mainframe, mini and micro. This classification is based principally on its computing power.

Languages

Computer languages are smaller and simpler than human languages. The natural language of the computer has restricted vocabulary.

Three types of computer languages have evolved over the years : machine code, assembly code, and high level code. Both machine code and assembly code are called low level languages as opposed to the high level language.

Operations

Computers are capable of performing only four basic operations : (i) input and output operations ; (ii) arithmetic and logical operations ; (iii) movement of data within the CPU (Central Processing Unit) ; and (iv) primitive comparison / logic operations.

Memory

In computer memory, we store a vast array of information about ourselves, our businesses, our scientific research data and so on. We search that our memory looking for the information, apropriate to a particluar task. And we edit the information we obtain — augmenting, deleting, or replacing — in order to extend or correct it. Storing, retrieving, or editing information requires specification of methods by which users interface the computer system.

Information stored in a computer includes numerical, textual, and graphical materials. Such information can be collected and ordered for presentation to the computer user. Ordered collections of information entities, such as textual paragraphs, graphical line drawings, or numerical tables, are known as 'documents'. A document is an object composed of a hierarchy of more primitive objects, each object being an 'instance' of a 'class' that defines the possible constituents and representations of the instances.

Objects are further classified as either *abstract* or *concrete*. An abstract object is denoted by an identifier and the class to which it belongs, while concrete objects are defined over one or more two-dimensional 'page-spaces', and represent the possible formatted images of abstract objects. Mapping from abstract objects to concrete objects are defined as 'formatting' operations. An important part of an abstract to concrete object mapping is the page-space domain of the concrete object.

The document processing operations are divided into three types : editing, formatting and viewing, depending on the domain and range-objects. Many other kinds of operations, such as numbering figures, equations, correcting spelling, and indexing terms, deal directly with the objects resulting from either editing or formatting.

Another important class of operations is 'filing'. Like most computer systems, document-processing systems require facilities for storing and accessing files of abstract and concrete objects.

Cache Memory

Cache memories are small, high-speed buffer memories used in modern computer systems to hold temporarily the portions of the contents of main memory which are currently in use. Information located in cache memory may be accessed in much less time than that located in main memory. Thus a central processing unit (CPU) with a cache memory needs to spend less time for waiting for instructions and operands to be fetched and / or stored. Virtually, all modern large computer systems have cache memories.

Optimizing the design of a cache memory generally has four aspects : (i) maximizing the probability of finding a memory reference's target in the cache (the hit ratio), (ii) minimizing the time to access information that is needed in the cache (access time) ; (iii) minimizing the delay due to a miss ; and (iv) minimizing the overheads of updating main memory, maintaining multi cache consistency etc.

Thus it is seen that there are two aspects to the performance of a cache memory : 'access time', and 'miss ratio'.

Computer Graphics

Computer Graphics is the use of a computer to define, store, manipulate, interrogate and present pictorial output. This is essentially a passive operation. The computer prepares and presents stored information to an observer in the form of picture.

The observer has no direct control over the picture being presented.

Pictures ultimately consist of points and a drawing algorithm to display them. This information is generally stored in a file prior to being used to present the picture. This file is called a data base. The data used to prepare the picture for presentation is rarely the same as that used to present picture. The data used to present picture, is frequently called a 'display file'. The display file represents some portion, view or scene of the picture represented by the total data base. The displayed picture is usually formed by rotating, translating, scaling and performing various projections on the data.

Computer Graphics is a complex and diversified technology. The end product of computer graphics is a picture which may, of course, be used for a large variety of purposes. Here the word 'picture' is used here in its broad sense to mean any collection of lines, points, texts etc. displayed on a graphic device.

A number of particular common terms and definitions are used in computer technology, which are inter alia computer aided design (CAD), interaction graphics (IG), computer graphics (CG) and computer aided manufacturing (CAM). These terms are frequently used interchangeably or in such a manner that considerable confusion sometimes may arise as to their precise meaning.

In the majority of applications computers are a long way from ever replacing human judgement. They provide people with the opportunity to pursue more creative endeavours and the exercise of values that are peculiarly human. In business and commerce they have complemented rather than replaced the workforce. The use of computer technology has also helped to create new products and services, sometimes altering work patterns, and bringing a high degree of automation to the offices and industries.

Industrial robots are programmable devices designed to manipulate tools, to transport parts and perform manufacturing tasks. A robot can be taught by guiding it through its intended role just once in so-called 'teach and learn' mode, its movements and actions directly controlled by a computer programme in proper time. Intelligent robots are anticipated in the future, which will be equipped with some measure of visual perception.

Computers are pointing the way to an automated society. The development of robots to work in certain hostile situations, such as fire-fighting, mines, security of sensative establishments and space exploration, could bring considerable benefits. Some industrial countries have already cut their production costs, by using computers, and considearbly by their investment in robots. In near future, society has to decide between the use of robots and the gainful employment of people.

The Computer Policy announced by the Government of India has been hailed as a boon at bringing remarakble changes in the Computer Science in India.

Indian manufacturers came out with IBM computible micro-computers. The IBM-PC, PC/XT and PC/AT have set the international standard for the industry and by making the Indian computer IBM compatible, easy access was provided to the vast amount of software developed over the years.

Most of the microcomputers support the languages FORTRAN and COBOL, besides BASIC : and only some support languages like PL/1, APL, PASCAL, LISP, C and ADA.

The price of a computer is dependent upon the amount of RAM, the numper of terminals, the number of floppy and hard disk drives, the microprocessor employed and the software which goes with the whole system.

A microcomputer is, however, a relatively expensive piece of equipment, and is perhaps intended to last for a long time.

A computer may be required :

* as a word processing system
* as a means of home entertainment
* as a means to understand programming
* to maintain name and address files
* to control a manufacturing process

- to prepare the pay-roll for an establishment
- to communicate with a data base available on computer distributed network system
- to maintain business accounts
- to teach students computer science and programming languages
- for scientific computations etc.

A computer is a very sensitive and costly instrument. Hence it should be installed in a very good room, and to protect it from dirt, dust and smoke, air-conditioning of the room is important. A voltage stabilizer (Servo-type) and an isolation transformer (to avoid the damage of the HDD due to spikes in the A. C. supply) are also essential.

A better quality printer, instead of, or in addition to, a dot-matrix printer, is also essential.

The main memory requirements should be guaged keeping in mind the combined requirements of the operating system : the typical application programme envisaged, and the in-memory data storage required.

While about 1,00,000 microcomputers have already been installed in India by the middle of 1990, the demand in the country for them is incresing every day. In addition to its use in offices and industries, there has also been a remarkable trend to introduce microcomputers in schools and colleges to enable computer literacy to spread uniformly across the length and breadth of the city.

The Computer Society of India is a forum where computer manufacturers, users, acadimicians, Government officials and students get together to exchange their views and discuss development in computer technology, Government policies, etc. The CSI continuously propagates productive use of computer, providing training programme and organizing convention.

Thus it appears that many benefits have undoubtedly been derived from the invention of computer which seems destined to bring about radical changes and create a better world for man to live in. The world stands today on the threshold of a computer age.

MAJOR PROJECTS IN INDIA

Irrigation and Multipurpose Projects

Nagarjunasagar (Andhra Pradesh): On the Krishna river near Nandikona village.

Tungabhadra (Joint project of Andhra Pradesh and Karnataka): On the Tungabhadra river.

Pochambad (Andhra Pradesh): Across Godavari river.

Gandak (Joint project of Bihar and Uttar Pradesh): Nepal also derives irrigation and power benefits from this project.

Kosi (Bihar): A multipurpose project, which serves Bihar and Nepal.

Kakrapara (Gujarat): On the Tapi river near Kakrapara in Surat district.

Ukai (Gujarat): A multipurpose project across Tapi river near Ukai village.

Mahi (Gujarat): A two-phase project, one across the Mahi river near Wanakbori village and the other across Mahi river near Kadana.

Bhadra (Karnataka): A multipurpose project across the river Bhadra.

Upper Krishna (Karnataka): A project consisting of Narayanpur dam across the Krishna river and a dam at Almatti.

Malaprabha (Karnataka): A dam across the Malaprabha in Belgaum district.

Tawa (Madhya Pradesh): A project across the Tawa river. a tributary of the Narmada, in Hoshangabad district.

Chambal (Joint project of Madhya Pradesh and Rajasthan): The project comprises Gandhi Sagar dam, Rana Pratap Sagar dam and Jawahar Sagar dam.

Bhima (Maharashtra): Comprises two dams, one on the Pawana river near Phagne in Pune district and the other across the Krishna river near Ujjain in Sholapur district.

Jayakwadi (Maharashtra) : A spillway across the river Godavari.

Hirakund (Orissa) : World's longest dam is located on the Mahanadi river.

Mahanadi Delta Scheme (Orissa) : The irrigation scheme will utilise releases from the Hirakund reservoir.

Bhakra Nangal (Joint project of Punjab, Haryana and Rajasthan) : India's biggest multipurpose river valley project comprises a straight-gravity dam across the Sutlej at Bhakra, the Nangal dam, Nangal hydel channel, two power houses at Bhakra dam and two power stations at Ganguwal and Kotla.

Beas (Joint venture of Haryana, Punjab and Rajasthan) : It consists of Beas-Sutlej Link and Beas Dam at Pong.

Rajasthan Canal (Rajasthan) : The project uses water releases from Pong dam and provides irrigation facilities to the north-western region of Rajasthan i.e. a part of the Thar desert.

Parambikulam-Aliyar (Joint venture of Tamil Nadu and Kerala) : The project envisages the integrated harnessing of eight rivers, six in the Anamalai Hills and two in the plains.

Ramganga (Uttar Pradesh) : A dam across Ramganga, a tributary of the Ganga river, is located in Garhwal district.

Farakka (West Bengal) : The project works for the preservation and maintenance of Calcutta port and for improving the navigability of the Hooghly. It comprises a barrage across the Ganga at Farakka, a barrage at Jangipur across the Bhagirathi and a feeder canal taking off from the Ganga at Farakka and tailing into the Bhagirathi below the Jangipur barrage.

Mayurakshi (West Bengal) : An irrigation and hydro-electric project comprises the Canada dam.

Kangsabati (West Bengal) : The project envisages construction of dams on the Kangsabati and Kumari rivers.

Damodar Valley Project (West Bengal and Bihar) : A multipurpose project for the unified development of irrigation, flood control and power generation in West Bengal and Bihar. It comprises multipurpose dams at Tilaiya, Konar, Maithon and Panchet, hydel power stations at Tilaiya, Maithon and Panchet, barrage at Durgapur and thermal power houses at Bokaro, Chandrapura and Durgapur. The project is administered by the Damodar Valley Corporation.

Power Projects

Machhkund hydro-electric project : Andhra Pradesh and Orissa
Srisailam hydro-electric project : Andhra Pradesh
Kothagudam thermal project : Andhra Pradesh
Lower Sileru hydro-electric project : Andhra Pradesh
Upper Sileru power station : Andhra Pradesh
Naharkatiya thermal project : Assam
Barauni thermal power station : Bihar
Patratu thermal power station : Bihar
Badarpur thermal power station : Delhi
Dhuvaran thermal power station : Gujarat
Ukai thermal power project : Gujarat
North Gujarat thermal power station : Gujarat
Baira-Siul hydro-electric project : Himachal Predesh
Salal hydro-electric project : Jammu and Kashmir
Sharvati hydro-electric project : Karnataka
Kalinadi hydro-electric project : Karnataka
Idikki hydro-electric project : Kerala
Sabarigiri project : Kerala
Korba thermal project : Madhya Pradesh
Satpura thermal project : Madhya Pradesh and Rajasthan
Koyna hydro-electric project : Maharashtra
Trombay thermal power project : Maharashtra
Nasik power station : Maharashtra
Koradi thermal power station : Maharashtra
Loktak hydro-electric project : Manipur
Hirakund hydro-electric project : Orissa
Balimela hydro-electric project : Orissa and Andhra Pradesh
Talcher thermal power station : Orissa

Guru Nanak thermal power station : Punjab
Ennore thermal power station : Tamil Nadu
Mettur project : Tamil Nadu
Neyveli thermal power station : Tamil Nadu
Kundah power station : Tamil Nadu
Harduaganj thermal station : Uttar Pradesh
Rihand hydro-electric project : Uttar Pradesh
Yamuna hydro-electric project : Uttar Pradesh
Panki thermal power station : Uttar Pradesh
Maneri-Bhali hydro-electric project : Uttar Pradesh
Obra thermal power station : Uttar Pradesh
Bandel thermal power station : West Bengal
Santaldih thermal scheme : West Bengal

Nuclear Power Stations

India's first nuclear power station at Tarapur near Bombay has been in operation since October 1969. There are two more stations, one at Kota in Rajasthan and the other at Kalpakkam near Madras, and a fourth station is also in operation at Narora in Uttar Pradesh.

Public Sector Industrial Undertakings

Bharat Aluminium Co. Ltd., New Delhi
Bharat Electronics Ltd., Jalhalli, Bangalore
Bharat Gold Mines Ltd., Gorgaum (Karnataka)
Bharat Heavy Electricals Ltd., Bhopal, Hardwar, Hyderabad and Tiruchirappalli
Bharat Heavy Plate and Vessels Ltd., Visakhapatnam
Bharat Ophthalmic Glass Ltd., Durgapur
Bharat Steel Ltd., Bokaro
Cement Corporation of India, New Delhi
Chittaranjan Locomotive Works, Chittaranjan
Cotton Corporation of India, New Delhi
Diesel Locomotive Works, Varanasi
Engineers India Ltd., New Delhi

Fertilizer Corporation of India [Operating units at Sindri (Bihar), Nangal (Punjab), Trombay (Maharashtra), Gorakhpur (UP), Namrup (Assam) and Durgapur (West Bengal)]
Garden Reach Workshops Ltd., Calcutta
Heavy Engineering Corporotion, Ranchi
Heavy Vehicles Factory, Avadi, Madras
Hindustan Antibiotics Ltd., Pimpri (Pune) and Rishikesh (UP)
Hindustan Aeronautics Ltd., Bangalore
Hindustan Cables Ltd., Rupnarainpur (West Bengal)
Hindustan Copper Ltd., Calcutta
Hindustan Housing Factory, New Delhi
Hindustan Insecticides Ltd., New Delhi
Hindustan Machine Tool Ltd., Bangalore, Pinjore (Haryana), Kalamssery (Kerala) and Hyderabad
Hindustan Organic Chemicals Ltd., Kolaba (Maharashtra)
Hindustan Paper Corporation Ltd., New Delhi
Hindustan Photo Films Manufacturing Co. Ltd., Ootacamund
Hindustan Shipyard, Visakhapatnam
Hindustan Steel Ltd., Ranchi (Bihar)
(Steel Plants at Bhilai, Durgapur and Rourkela)
Hindustan Teleprinters Ltd., Madras
Hindustan Zine Ltd., Udaipur (Rajasthan)
Indian Drugs and Pharmaceuticals Ltd., New Delhi (Antibiotics Plant, Rishikesh ; Synthetic Drugs Plant, Hyderabad ; Surgical Instruments Plant, Madras)
Indian Iron & Steel Co., Burnpur
Indian Oil Corporation, Bombay
Indian Petro-Chemicals Corporation, Vadodara
Indian Rare Earths Ltd., Alwaye (Kerala)
Indian Telephone Industries Ltd.. Bangalore
Instrumentations Ltd., Kota (Rajasthan)
Integral Coach Factory, Perambur, Madras
Jute Corporation of India, Calcutta
Machine Tool Corporation of India, Ajmer
Mazagon Dock, Bombay
Mining and Allied Machinery Corporation, Durgapur
National Instruments Ltd., Calcutta

National Mineral Development Corporation Ltd., Hyderabad
National Newsprint and Paper Mills Ltd,, Nepanagar
Scooters India Ltd., Lucknow
Steel Authority of India Ltd., New Delhi
Triveni Structurals, Naini (Allahabad)
Tungabhadra Steel Products Ltd., Tungabhadra (Karnataka)

National Laboratories and Research Institutes

Physical Sciences

Central Electronics Engineering Research Institute, Pilani
Central Scientific Instruments Organisation, Chandigarh
National Geo-Physical Research Institute, Hyderabad
National Institute of Oceanography, Panaji (Goa)
National Physical Laboratory, New Delhi

Chemical Sciences

Central Electro-Chemical Research Institute, Karaikudi
Central Salt and Marine Chemical Research Institute, Bhavnagar
Indian Institute of Petroleum, Dehra Dun
National Chemical Laboratory, Pune

Biological Sciences

Central Drug Research Institute, Lucknow
Central Food Technological Research Institute, Mysore
Central Indian Medicinal Plants Organisation, Lucknow
Central Leather Research Institute, Madras
Central Public Health Engineering Research Institute, Nagpur
Industrial Toxicology Research Centre, Lucknow
Institute of Experimental Medicine, Calcutta
National Botanical Gardens, Lucknow

Engineering

Central Building Research Institute, Roorkee
Central Fuel Research Institute, Jeargora (Bihar)

Central Glass and Ceramic Research Institute, Jadavpur, Calcutta
Central Mechanical Engineering Research Institute, Durgapur (West Bengal)
Central Mining Research Station, Dhanbad (Bihar)
Central Road Research Institute, New Delhi
National Aeronautical Laboratory, Bangalore
National Metallurgical Laboratory, Jamshedpur
Structural Engineering Research Centre, Roorkee

Scientific Museums

Birla Industrial and Technological Museum, Calcutta
Indian National Scientific Documentation Centre, New Delhi
Visvesvaraya Industrial and Technological Museum, Bangalore

Cooperative Research Institutions

Ahamedabad Textile Industry's Research Association, Ahmedabad
Automotive Research Association of India, Bombay
Bombay Textile Research Association, Bombay
Cement Research Institute of India, Ballavgarh
Indian Jute Industries' Research Association, Calcutta
Indian Plywood Industries' Research Institute, Bangalore
Silk and Art Silk Mills' Research Association, Bombay
South India Textile Research Association, Coimbatore
Tocklai Experimental Station, Jorhat
Wool Research Association, Bombay

Medical Research

All-India Institute of Medical Sciences, New Delhi
All-India Institute of Speech and Hearing, Mysore
Cholera Research Centre, Calcutta
Indian Council of Medical Research, New Delhi
Indian Registry of Pathology, New Delhi
Institute for Research in Reproduction, Bombay
National Institute of Occupational Health, Ahmedabad
National Institute of Nutrition, Hyderabad

Post-Graduate Institute of Medical Education and Research, Chandigarh
Tuberculosis Chemotherapy Centre, Madras
Virus Research Centre, Pune

Study of Diseases and Treatment

All-Indian Institute of Hygiene and Public Health, Calcutta
Cancer Institute, Madras
Central Drugs Laboratory, Calcutta
Central Leprosy Teaching and Research Institute, Chingleput
Chittaranjan Cancer Research Centre, Calcutta
Indian Cancer Research Centre, Bombay
National Institute of Communicable Diseases, Delhi
(formerly known as Malaria Institute of India)
National Tuberculosis Institute, Bangalore
School of Tropical Medicine, Calcutta
Vallabhbhai Patel Chest Institute, Delhi

Micro-Biology and Related Studies

Central Research Institute, Kasauli
Haffkine Institute, Bombay
King Institute of Preventive Medicine, Guindy, Madras
Pasteur Institute, Coonor

Departmental Research Centres

Anthropological Survey of India, Calcutta
Central Water and Power Research Station, Khadakvasla (Pune)
Central Power Research Institute, Bangalore and Bhopal
Forest Research Institute, Dehra Dun
Geological Survey of India, Calcutta
Indian Institute of Tropical Meteorology, Pune
Indian Institute of Astrophysics, Kodaikanal
Indian Institute of Geomagnetism, Bombay
Indian Roads Congress, New Delhi (Ministry of Transport)
Telecommunication Research Centre, New Delhi (P & T Department)
Research, Designs and Standards Organisation, Lucknow (Railways)

Nuclear and Space Research Centres

Nuclear Research

Atomic Energy Commission, Bombay
Bhabha Atomic Research Centre, Trombay (Bombay)
Electronics Corporation of India, Hyderabad
High Altitude Research Laboratory, Gulmarg (Kashmir)
Indian Rare Earths Ltd., Alwaye
Radio Astronomy Centre, Ootacamund
Saha Institute of Nuclear Physics, Calcutta
Tata Institute of Fundamental Research, Bombay
Tata Memorial Centre, Bombay
Uranium Corporation of India, Jaduguda (Bihar)

Space Research

Indian Scientific Satellite Project, Bangalore
Indian Space Research Organisation, Bangalore
Physical Research Laboratory, Ahmedabad
Propelling Fuel Complex, Trivandrum
Satellite Launch Vehicle Project, Trivandrum
Space Applications Centre, Ahmedabad
Space Commission, Bangalore
Sriharikota Range, Sriharikota (Andhra Pradesh)
Thumba Equatorial Rocket Launching Station, Thumba
Vikram Sarabhai Space Centre, Trivandrum

National Surveys and Other Institutions

Botanical Survey of India, Calcutta
Birbal Sahni Institute for Palaeobotany, Lucknow
Bose Research Institute. Calcutta
Indian Association for the Cultivation of Science, Calcutta
National Atlas Organisation, Calcutta
Indian National Science Academy, New Delhi
Indian National Science Congress Association, Calcutta
Raman Research Institute, Bangalore
Survey of India, Dehra Dun
Wadia Institute of Himalayan Zoology, Delhi
Zoological Survey of India, Calcutta

About the Book

Science in India has an ancient tradition. Ancient India possessed advanced knowledge in various branches of science: Ayurveda, Astronomy, Mathematics etc. The knowledge and practice of cesarian, bone-setting, and even plastic surgery had also developed far beyond anything elsewhere in those days. The zero and the numericals, and the decimal system are rightly recognized as Indian contributions to the world scinece.

India is proud of her great scientists whose valuable contributions in the field of world science are significantly used. India is today self-reliant in all of her major modern scientific projects like nuclear energy, space research, computer science and others.

This book introduces the great Indian scientists, both ancient and modern.

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About the Author

Pranab Bandyopadhyay (b. 1925) obtained his M. A. degree in 'Modern Indian Languages' from Calcutta University in 1949; has been widely published in India and abroad; his biography has been included in 'International Who's Who in Poetry', and 'Men of Achievement' published by International Biographical Centre, Cambridge, England, and also in 'Indian Authors Who's Who' published by Sahitya Academy, India; has been awarded honorary D. Litt. in 1980.

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